AEA

Site Operators Manual

Automatic Urban and Rural Network

Defra and the Devolved Administrations
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Executive Summary

This manual has been written for the Local Site Operator (LSO) to provide both a general introduction to the Automatic Urban and Rural Network and also a hands on guide detailing the standard operating procedures and practices used in the network. The manual is divided into two parts. Part A is descriptive and contains general background information on the objectives, structure and management of the network as well as generic technical principles employed in site operation.

Part B of the manual contains operational instructions. The coloured pages describe the site operating procedures which are carried out by the LSO, whilst the white pages describe their responsibilities regarding non-routine site operations and equipment breakdown. As the operating procedures are equipment specific, a set of instructions is provided for each analyser type. These pages are therefore colour-coded according to instrument manufacturer, in order to distinguish the equipment to which they apply. Should it be necessary to replace an analyser with one from a different manufacturer, or should a new analyser be installed, then QA/QC Unit will provide appropriate instructions for any equipment approved for use in the AURN.

The Automatic Urban and Rural Network site operator's manual is a working document prepared by the QA/QC Unit and subject to continual update, as equipment or procedures change. Numbered copies of the manual are issued to specific owners, who are directly involved with the network. A register of these owners is kept and all updates are sent directly to them. The un-numbered copies are not registered and no updates will be supplied. They are therefore complete with amendments only up to the date shown on the front cover. It should not be assumed that these represent the latest version of the manual.

An electronic version of this manual is also available on the world wide web.

http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html

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Please Note:

Part B QA/QC Data Ratification and Intercalibration Report for the Automatic Urban and Rural Network July-September 2008 is a separate document

Part A
General Information

1 Introduction: The Automatic Urban and Rural Monitoring Network

The Automatic Urban and Rural Network (AURN) is operated on behalf of the Department for Environment, Food and Rural Affairs (defra), the Welsh Assembly Government, The Scottish Government and the Department of the Environment in Northern Ireland, collectively referred to as the Devolved Administrations (DA's).

As of February 2009, the AURN consists of 125 monitoring stations. 61 of these monitoring stations are directly funded by Defra and the Devolved Administrations, and a further 64 affiliated sites are owned and operated by Local Authorities, of which 8 sites comprise in the London Air Quality Network (LAQN). The AURN was formed by the amalgamation of the former Enhanced Urban Network (EUN), the Statutory Urban Network (SUN), the Rural Monitoring Network and the inclusion of the monitoring stations from the LAQN. Further expansion of the network is planned for 2009 with the addition of several new sites

The AURN was formed by the amalgamation of the former Enhanced Urban Network (EUN), the Statutory Urban Network (SUN), the Rural Monitoring Network and the inclusion of the monitoring stations from the LAQN and the network has grown and developed over many years.

The pollutants monitored in the network are oxides of nitrogen (NOx), sulphur dioxide (SO2), ozone (O3), carbon monoxide (CO) and particles (PM10 and PM2.5). The pollutants monitored at the sites and their locations are shown in Figure 1.1 (Urban and Rural sites). Table 1.1 gives a list of all the current operational sites in the Network. Further information regarding monitoring site locations and pollutants can be accessed via the World Wide Web at http://www.bv-aurnsiteinfo.co.uk/

The AURN is primarily targeted at providing the necessary data for legal compliance with EU Air Quality Directives. However, air pollution policy development in the UK relies on all of the national air quality monitoring networks to provide basic data on air pollutant concentrations. Such data are necessary to establish priorities for policy action and to assess the effectiveness of action in reducing air pollution concentrations.

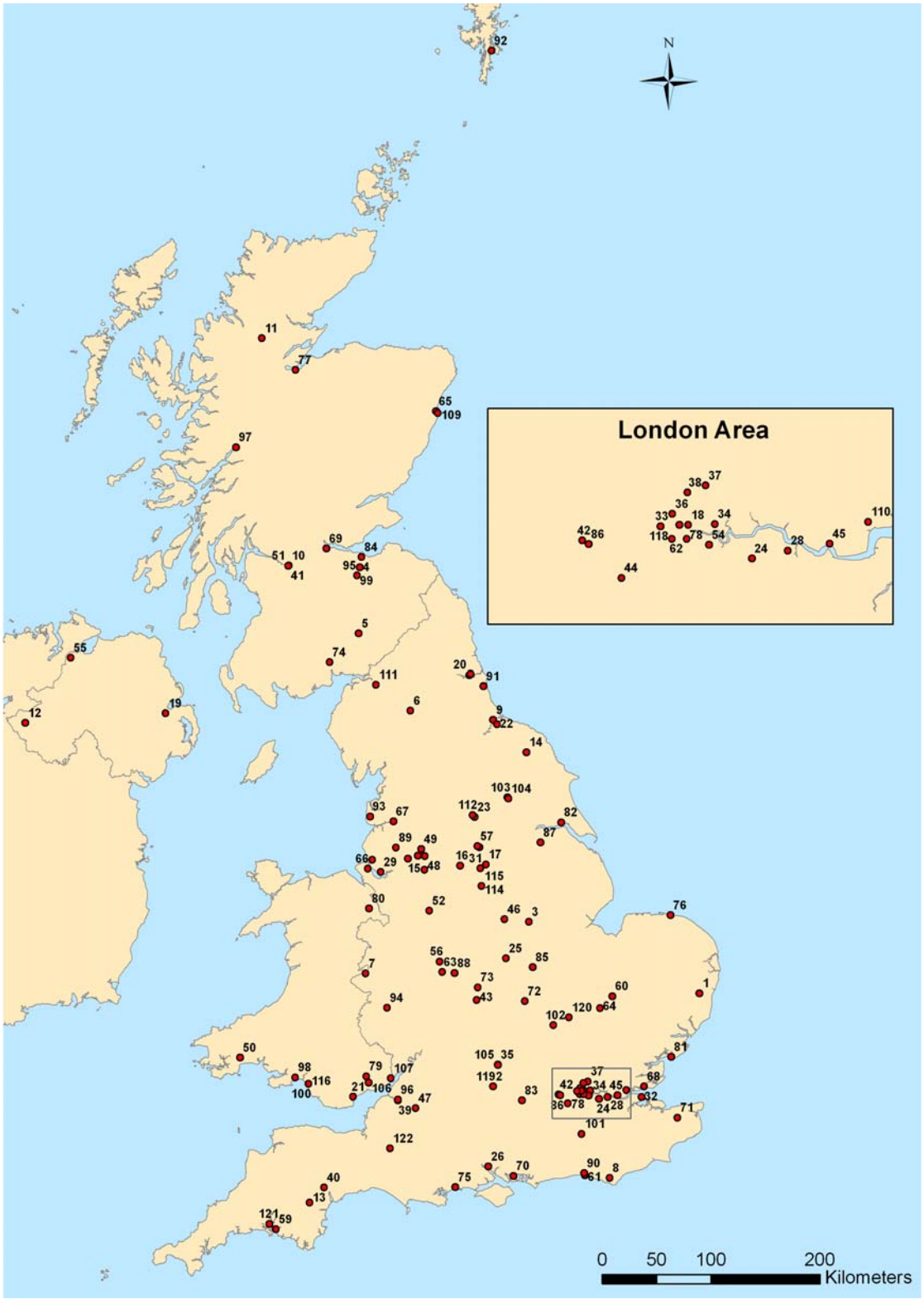

N
London Area
0 50 100 200
Kilometers

Table 1.1: Monitoring sites in the AURN – February 2009 (the numbering of the sites relates to the site map shown in Figure 1.1)

1	Sibton	O3	41	Glasgow Centre	CO NO2 O3 PM10 PM25 SO2	81	St Osyth	CO NO2 O3
2	Harwell	NO2 O3 PM10 PM25 SO2	42	London Hillingdon	NO2 O3	82	Hull Freetown	CO NO2 O3 PM10 PM25 SO2
3	Bottesford	O3	43	Leamington Spa	NO2 O3 PM10 PM25 SO2	83	Reading New Town	NO2 O3 PM10 PM25
4	Bush Estate	NO2 O3	44	London Teddington	NO2 O3 PM25	84	Edinburgh St Leonards	CO NO2 O3 PM10 PM25 SO2
5	Eskdalemuir	NO2 O3	45	Thurrock	NO2 O3 PM10 SO2	85	Market Harborough	CO NO2 O3
6	Great Dun Fell	O3	46	Nottingham Centre	NO2 O3 PM25 SO2	86	London Harlington	NO2 O3 PM10 PM25
7	Aston Hill	NO2 O3	47	Bath Roadside	NO2	87	Scunthorpe Town	NO2 PM10 SO2
8	Lullington Heath	NO2 O3 SO2	48	Manchester South	NO2 O3	88	Birmingham Tyburn	NO2 O3 PM10 PM25 SO2
9	Billingham	NO2	49	Bury Roadside	CO NO2 PM10	89	Wigan Centre	NO2 O3 PM25
10	Glasgow City Chambers	NO2	50	Narberth	NO2 O3 PM10 SO2	90	Brighton Preston Park	NO2 O3 PM25
11	Strath Vaich	O3	51	Glasgow Kerbside	NO2 PM10	91	Sunderland Silksworth	NO2 O3 PM25 SO2
12	Lough Navar	O3 PM10	52	Stoke-on-Trent Centre	NO2 O3 PM10 PM25	92	Lerwick	O3
13	Yarner Wood	NO2 O3	53	Salford Eccles	CO NO2 O3 PM10 PM25 SO2	93	Blackpool Marton	NO2 O3 PM10
14	High Muffles	NO2 O3	54	Southwark Roadside	NO2	94	Leominster	NO2 O3 SO2
15	Glazebury	NO2 O3	55	Derry	NO2 O3 PM10 PM25 SO2	95	Auchencorth Moss	O3 PM10 PM25
16	Ladybower	NO2 O3 SO2	56	Walsall Willenhall	NO2	96	Bristol St Paul's	CO NO2 O3 PM10 PM25 SO2
17	Sheffield Tinsley	NO2	57	Barnsley Gawber	NO2 O3 SO2	97	Fort William	NO2 O3
18	London Bloomsbury	CO NO2 O3 PM10 PM25 SO2	58	London Marylebone Road	CO NO2 O3 PM10 PM25 SO2	98	Swansea Roadside	NO2 PM10 PM25
19	Belfast Centre	CO NO2 O3 PM10 PM25 SO2	59	Plymouth Centre	NO2 O3 PM10	99	Auchencorth Moss PM10 PM25	PM10 PM25
20	Newcastle Centre	CO NO2 O3 PM10 PM25 SO2	60	Wicken Fen	NO2 O3 SO2	100	Port Talbot Margam	CO NO2 O3 PM10 PM25 SO2
21	Cardiff Centre	CO NO2 O3 PM10 PM25 SO2	61	Brighton Roadside	NO2	101	Horley	NO2
22	Middlesbrough	CO NO2 O3 PM10 PM25 SO2	62	London Cromwell Road 2	CO NO2 SO2	102	Stewartby	SO2
23	Leeds Centre	CO NO2 O3 PM10 PM25 SO2	63	Sandwell West Bromwich	NO2 O3 SO2	103	York Bootham	PM10 PM25
24	London Eltham	NO2 O3 PM25	64	Cambridge Roadside	NO2	104	York Fishergate	NO2 PM10
25	Leicester Centre	CO NO2 O3 PM10 PM25 SO2	65	Aberdeen	NO2 O3 PM10	105	Oxford St Ebbes	NO2 PM10 PM25
26	Southampton Centre	CO NO2 O3 PM10 PM25 SO2	66	Wirral Tranmere	NO2 O3 PM25	106	Newport	NO2 PM10 PM25
27	Barnsley 12	SO2	67	Preston	NO2 O3 PM25	107	Chepstow A48	NO2 PM10

28	London Bexley	CO NO2 PM25 SO2	68	Southend-on-Sea	NO2 O3 PM10	108	Liverpool Queen's Drive Roadside	NO2
29	Liverpool Speke	CO NO2 O3 PM10 PM25 SO2	69	Grangemouth	NO2 PM10 PM25 SO2	109	Aberdeen Union Street Roadside	NO2
30	Manchester Piccadilly	NO2 O3 PM25	70	Portsmouth	NO2 O3 PM10 PM25	110	Stanford-le-Hope Roadside	NO2 PM10 SO2
31	Sheffield Centre	CO NO2 O3 PM10 PM25 SO2	71	Canterbury	NO2	111	Carlisle Roadside	NO2 PM10
32	Rochester Stoke	NO2 O3 PM10 PM25 SO2	72	Northampton	NO2 O3 PM10 SO2	112	Leeds Headingley Kerbside	NO2 PM10
33	London N. Kensington	CO NO2 O3 PM10 SO2	73	Coventry Memorial Park	NO2 O3 PM25	113	Newcastle Cradlewell Roadside	NO2
34	Tower Hamlets Roadside	CO NO2	74	Dumfries	NO2	114	Chesterfield Roadside	NO2 PM10
35	Oxford Centre Roadside	NO2	75	Bournemouth	NO2 O3 PM10	115	Chesterfield	NO2 PM10 PM25
36	Camden Kerbside	NO2 PM10	76	Weybourne	O3	116	Port Talbot Margam PM2.5	PM25
37	Haringey Roadside	NO2 PM10	77	Inverness	NO2 PM10	117	London Marylebone Road PARTISOL	PM10 PM25
38	London Haringey	NO2 O3	78	London Westminster	CO NO2 O3 PM10 SO2	118	London N. Kensington PARTISOL	PM10 PM25
39	Bristol Old Market	CO NO2	79	Cwmbran	NO2 O3	119	Harwell PARTISOL	PM25
40	Exeter Roadside	NO2 O3	80	Wrexham	NO2 PM10 SO2	120	Sandy Roadside	NO2 PM10
						121	Saltash Roadside	PM10
						122	Charlton Mackrell	NO2 O3

1.1 History of the Network

Research measurements of air pollution with automatic analysers commenced in the early 1970's in the UK. Later, such measurements were required for regulatory purposes and the Statutory Urban Network (SUN) was established in 1987 to monitor for compliance with EC Directive limit values on air quality. To compliment this network the Department commissioned the Enhanced Urban Network (EUN) in 1992. This network was established as a result of the 1990 White Paper on the Environment 'This Common Inheritance' which committed the Government to a significant expansion in urban air quality monitoring in the UK. In particular, it also identified the need to improve public availability of air quality information.

Phase one of the EUN network implementation involved establishing 12 urban background monitoring stations measuring five pollutants (CO, NO_x, SO_2, O_3 and PM_{10}). Phase two took place in 1993 with the addition of a further 12 urban background sites and 13 stations monitoring Volatile Organic Compounds (VOCs).

In 1993 the Department also launched the "Air Quality Monitoring Progress and Partnership" initiative to promote integration of local authority sites into the national monitoring network where this met the national objectives.

In 1995 the Enhanced Urban Network and Statutory Urban Network were amalgamated to form the Automatic Urban Network (AUN) consisting, at the time, of 26 sites directly funded by the Department and 4 affiliated local authority sites. Throughout the next five years over 50 local authority sites were subsequently integrated into the network including 14 of the London Air Quality Monitoring Network sites. In 1998 the separate urban and rural networks were combined to form the joint Automatic Urban and Rural Network (AURN) consisting of 103 sites.

In order to ensure consistency throughout the network, affiliated monitoring stations have all QA/QC functions (calibration gases, data ratification, operator training) and data collection by the Management Unit, funded by defra and the DAs. All other costs associated with the monitoring station are the responsibility of the Local Authority.

Since 2001, further expansion of the network has taken place in order to comply with the requirements of the European Air Quality Directives. During 2008, the network has again been expanded in site numbers extensive monitoring of $PM_{2.5}$ has been included into the network to comply with the new Air Quality Directive[1] published in 2008.

[1] Directive 2008/50/EC of The European Parliament and of The Council of 21 May 2008 on ambient air quality and cleaner air for Europe
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF

1.2 Air Quality Directives

There have been considerable changes in European air quality legislation in the last few years and the AURN has been expanded and adapted to conform to these new requirements. The Air Quality Framework Directive (1996/62/EC) on ambient air quality assessment and management set the framework for air quality assessment and management throughout Europe via a system of Daughter Directives giving specific requirements and limit values for a range of pollutant species. Four Daughter Directives were issued. However, with the exception of the fourth Daughter Directive, covering PAH and Benzene, the 1996 Framework Directive and the first 3 Daughter Directives have been superseded by the new (2008/50/EC) Air Quality Directive[1].

1.3 The Air Quality Strategy

In addition to the requirements of the EU, the UK has also adopted an Air Quality Strategy[2] for the UK as part of the requirements of The Environment Act 1995. The first Air Quality Strategy was published in 1997 and was updated in 2000, an addendum was produced in 2003 and a fully revised Strategy was published in July 2007. The Air Quality Strategy sets National Air Quality Objectives and proposes measures to be considered for achieving these (where they are not already met) in order to achieve "clean air for a good quality of life". Once again, the AURN provides information on current air quality, which has assisted in the preparation of the strategy, and provides the yardstick whereby compliance with the strategy can be assessed at a national level.

1.4 Local Authority Review and Assessment

The 1995 Environment Act put a requirement on Local Authorities to review and assess air quality in their area. AURN data from individual sites are widely used by Local Authorities in this assessment. In addition air pollution maps of the UK, based on measurement data from the AURN and emission data from the National Atmospheric Emissions Inventory, are provided for use by Local Authorities as part of their initial assessment.

Analysis of data from the AURN provides detailed information on trends for individual pollution species this helps to assess the effectiveness of air pollution control measures implemented. Many of the QA/QC measures developed with the AURN are highlighted in the Technical Guidance[3] provided to Local Authorities to assist them in carrying out their own monitoring programmes.

1.5 UK National Indicators of Sustainable Development

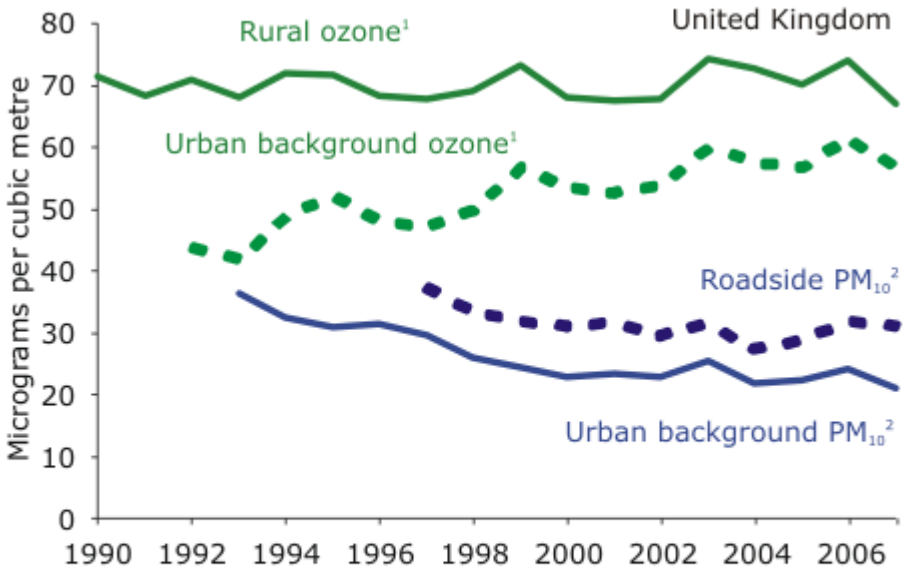
To support the UK Government Sustainable Development Strategy there is a suite of 68 national sustainable development indicators[4]. One of these indicators relates to urban and rural air quality – Number 61 Air Quality and Health.

Two parameters are assessed for this indicator:
(a) Annual levels of particles and ozone
(b) days when air pollution is moderate or higher

[2] The Air Quality Strategy for England, Scotland, Wales and Northern Ireland July 2007 http://www.defra.gov.uk/environment/airquality/strategy/
[3] Local Air Quality Management Technical Guidance LAQM TG (09) February 2009 http://www.defra.gov.uk/environment/airquality/local/guidance/index.htm
[4] Sustainable Development National Indicators http://www.defra.gov.uk/sustainable/government/progress/national/index.htm

The assessment is based on data from the AURN. The latest available trend plots for these indicators are shown below, using AURN data up to 2007. These will be updated in April 2009 when the ratified AURN dataset for 2008 is available.

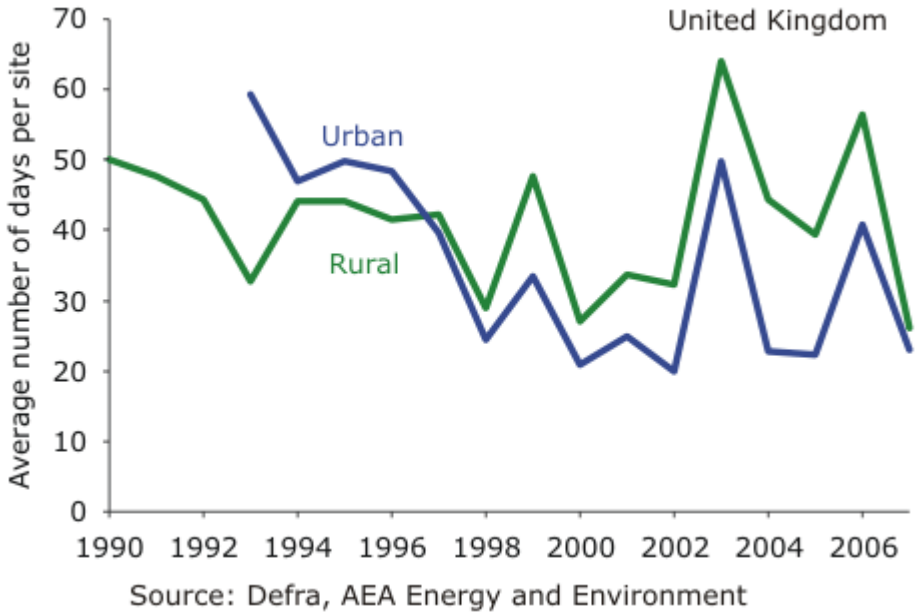
(a) Annual levels of particles and ozone, 1990 to 2007



1. Ozone index shows annual mean of the daily maximum 8 hour running mean.
2. PM_{10} index shows annual average.

Source: Defra, AEA Energy and Environment

(b) Days when air pollution is moderate or higher, 1990 to 2007



Source: Defra, AEA Energy and Environment

1.6 Network Management and Operation

The operation of such a large and geographically dispersed network as the AURN is de-centralised with many organisations involved in the day-to-day running of the network. The current structure of the network is outlined in Figure 1.2.

Currently the role of Central Management and Coordination Unit (CMCU) for the Automatic Urban and Rural Network is contracted to Bureau Veritas, whilst the Environmental Research Group (ERG) of King's College London has been appointed as Management Unit for the London Air Quality Network (LAQN).

AEA (part of AEA Group) undertake the role of Quality Assurance and Control Unit (QA/QC Unit) for the AURN, to provide an independent arbiter of network performance. The responsibility for operating individual stations in the network has been assigned to local organisations, such as local authority Environmental Health Officers with relevant experience in the field.

Calibration gases for the network are supplied by Air Liquide Ltd and are provided with a UKAS certificate of calibration by AEA (UKAS Calibration Laboratory 0401).

The various organisations participating in the network are given in Table 1.2. Contact names and telephone numbers for these organisations are given in Appendix E.

Because a variety of organisations are involved in operating and managing the network, it is essential that consistent procedures are adopted and implemented by all participants. To ensure this, operational methodologies and best practice are comprehensively documented by the QA/QC Unit.

1.7 Air Quality Communications Unit

Though not formally part of the AURN, the Air Quality Communications Unit has a vital role in disseminating the data to the public and media.

AURN monitoring data are uploaded every hour, as provisional data, to the UK Air Quality Information Archive website (www.airquality.co.uk) and to TELETEXT (page 156) and a freephone telephone information service (0800 556677). In addition, they are distributed daily to the media via the air quality bulletin service.

When the data have been further checked and ratified they are reissued to the Air Quality Information Archive website as ratified data. The daily data summaries and the hourly data provided to the web, TELETEXT, and the freephone telephone information service are primarily intended to inform the public of current air pollution conditions. Health advice is also provided so that sensitive individuals can take appropriate action, such as increased medication, staying indoors or reducing physical activity. This service also now fulfils the EU requirement for information to be provided to the public and for pollution alerts to be issued when specified alert thresholds are exceeded over a 3-hour period. During severe episodes, the Government may also issue advice to the public on how to reduce pollutant emissions by restricting car use or other polluting activities.

The 3 UK Devolved Administrations Scottish Government, Welsh assembly Government and the Department of the Environment in Northern Ireland also now all operate their own air quality websites, which also contain all of the AURN data for their respective areas:

http://www.scottishairquality.co.uk/
http://www.welshairquality.co.uk/
http://www.airqualityni.co.uk/

2 History of the Network

Research measurements of air pollution with automatic analysers commenced in the early 1970's in the UK. Later, such measurements were required for regulatory purposes and the Statutory Urban Network (SUN) was established in 1987 to monitor for compliance with EC Directive limit values on air quality. To compliment this network the Department commissioned the Enhanced Urban Network (EUN) in 1992. This network was established as a result of the 1990 White Paper on the Environment 'This Common Inheritance' which committed the Government to a significant expansion in urban air quality monitoring in the UK. In particular, it also identified the need to improve public availability of air quality information. Phase one of the EUN network implementation involved establishing 12 urban background monitoring stations measuring five pollutants (CO, NOx, SO_2, O_3 and PM_{10}). Phase two took place in 1993 with the addition of a further 12 urban background sites and 13 stations monitoring Volatile Organic Compounds (VOCs).

In 1993 the Department also launched the "Air Quality Monitoring Progress and Partnership" initiative to promote integration of local authority sites into the national monitoring network where this met the national objectives.

In 1995 the Enhanced Urban Network and Statutory Urban Network were amalgamated to form the Automatic Urban Network (AUN) consisting, at the time, of 26 sites directly funded by the Department and 4 affiliated local authority sites. Throughout the next five years over 50 local authority sites were subsequently integrated into the network including 14 of the London Air Quality Monitoring Network sites. In 1998 the separate urban and rural networks were combined to form the joint Automatic Urban and Rural Network (AURN) consisting of 103 sites.

In order to ensure consistency throughout the network, affiliated monitoring stations have all QA/QC functions (calibration gases, data ratification, operator training) and data collection by the Management Unit, funded by Defra and the DAs. All other costs associated with the monitoring station are the responsibility of the Local Authority.

Since 2001, further expansion of the network has taken place in order to comply with the requirements of the European Air Quality Daughter Directives. There has also been a programme to install PM2.5 analysers

Future expansion of the network is planned for 2009 with the incor of ozone and NOx analysers in rural and suburban areas to meet the requirements of the third Daughter Directives (see section 1.2).

The London Air Quality Network (LAQN) was formed in 1993 to co-ordinate and improve air pollution monitoring in London. The LAQN is facilitated by the Association of London Government on behalf of the thirty-three London Boroughs and is operated and managed by the Environmental Research Group (ERG) at King's College London. Each Borough funds monitoring in its own area. The core LAQN activities are funded by ERG itself. The Department for Environment, Food and Rural Affairs (Defra) and the Devolved Administrations (DAs) funds ERG to operate the Marylebone Road site and to maintain eight (currently) of the LAQN sites as affiliate sites to the UK Automatic Urban and Rural Network (AURN).

2.1 Air Quality Directives

There have been considerable changes in the European air quality legislation in the last few years, and the AURN has been expanded and adapted to conform to these new requirements. The Air Quality Framework Directive (1996/62/EC) on ambient air quality assessment and management5 sets the framework for air quality assessment and management throughout Europe via a system of Daughter Directives giving specific requirements and limit values for a range of pollutant species. Three Daughter Directives have now been issued, the first Daughter Directive6 (1999/30/EC) covering SO2, NO2, NOx, particulate matter and lead, the second Daughter Directive7 (2000/69/EC) covering CO and benzene and the third Daughter Directive8 (2002/3/EC) covering ozone which came into force on 9th September 2003. These Daughter Directives contain limit values and also upper and lower assessment threshold values which define areas where monitoring is required. To conform to the requirements of these Directives, additional monitors for NO2, SO2 and particulate matter were added to the AURN in 2001 and further monitors for CO were added in 2002. Additional monitors for O3 and rural NOx have been installed to comply with the third Daughter Directive on ozone, which had an implementation date of 9 September 2003. In addition to defining the extent of monitoring, these Directives also have specific data quality and data capture requirements.

2.2 The Air Quality Strategy

The development of the UK Air Quality Strategy over the last decade has been one of the major Government initiatives in air pollution control and research. The Expert Panel on Air Quality Standards examined all available evidence on health effects, together with data on current air quality in the UK, much of which was collected as part of the AURN and its predecessors, to develop recommended air pollution standards for the UK. These standards were formulated into objectives to be achieved by 2005 in the UK National Air Quality Strategy, first published in 1997. This strategy, and the objectives set, relied heavily on air pollution concentration data from all UK national monitoring networks, but especially from the AURN. The strategy was revised and updated in 2000, with air quality standards and objectives for eight key air pollutants to be achieved between 2003 and 2008. An Addendum to the Air Quality Strategy was issued on 6 February 2003. This introduced tighter objectives for particles, benzene and carbon monoxide and a new objective for polycyclic aromatic hydrocarbons.

Further information can be found at:-

http://www.defra.gov.uk/environment/airquality-strategy-addendum

2.3 Local Authority Review and Assessment

The 1995 Environment Act put a requirement on Local Authorities to review and assess air quality in their area. As a fundamental input to this process, air pollution maps of the UK were provided for use by Local Authorities as part of their initial assessment. These maps were based on measurement data from the AURN and emission data from the National Atmospheric Emissions Inventory. In later stages of the assessment, these maps were heavily supplemented by local measurements and modelling.

[5] Council Directive 96/62/EC on Ambient Air Quality Assessment and Management. OJ, L296/55, 21/11/1996
[6] Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide, oxides of nitrogen, particulate matter and lead in ambient air. OJ, L163/41, 29/6/1999.
[7] Directive 2000/69/EC of the European Parliament and of the Council relating to limit values for benzene and carbon monoxide in ambient air. OJ, L313/12, 13/12/2000
[8] Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air OJ, L67/14, 9/3/2002

However, the maps continued to provide the essential input of background concentrations to the modelling work undertaken by Local Authorities.

In order to assess the effectiveness of air pollution control measures implemented, it is necessary to have consistent and reliable measurement data over many years. For the principal inorganic compounds, this data is provided by the AURN. Analysis of data from the AURN provides detailed information on trends for individual pollution species. In addition, an overall indicator of the air pollution climate of the UK is calculated annually, from AURN data, and is one of the 15 UK Headline Indicators of Sustainable Development.

http://www.sustainable-development.gov.uk/indicators/headline/h10.htm

2.4 Network Management and Operation

The operation of such a large and geographically dispersed network as the AURN is de-centralised with many organisations involved in the day to day running of the network. The current structure of the network is outlined in Figure 2.1.

Currently the role of Central Management and Coordination Unit (CMCU) for the Automatic Urban and Rural Network is contracted to Bureau Veritas (BV), whilst the Environmental Research Group (ERG) of King's College London has been appointed as Management Unit for the London Air Quality Network (LAQN).

AEA undertake the role of Quality Assurance and Control Unit (QA/QC Unit) for the AURN, to provide an independent arbiter of network performance. The responsibility for operating individual stations in the network has been assigned to local organisations, such as local authority Environmental Health Officers with relevant experience in the field.

Calibration gases for the network are supplied by Air Liquide UK Ltd and are provided with a ISO17025 certificate of calibration by AEA (UKAS Calibration Laboratory 0401).

The various organisations participating in the network are given in Table 2.1. Contact names and telephone numbers for these organisations are given in Appendix E.

Because a variety of organisations are involved in operating and managing the network, it is essential that consistent procedures are adopted and implemented by all participants. To ensure this, operational methodologies and best practice are comprehensively documented by the QA/QC Unit.

Figure 2.1: Network Participants

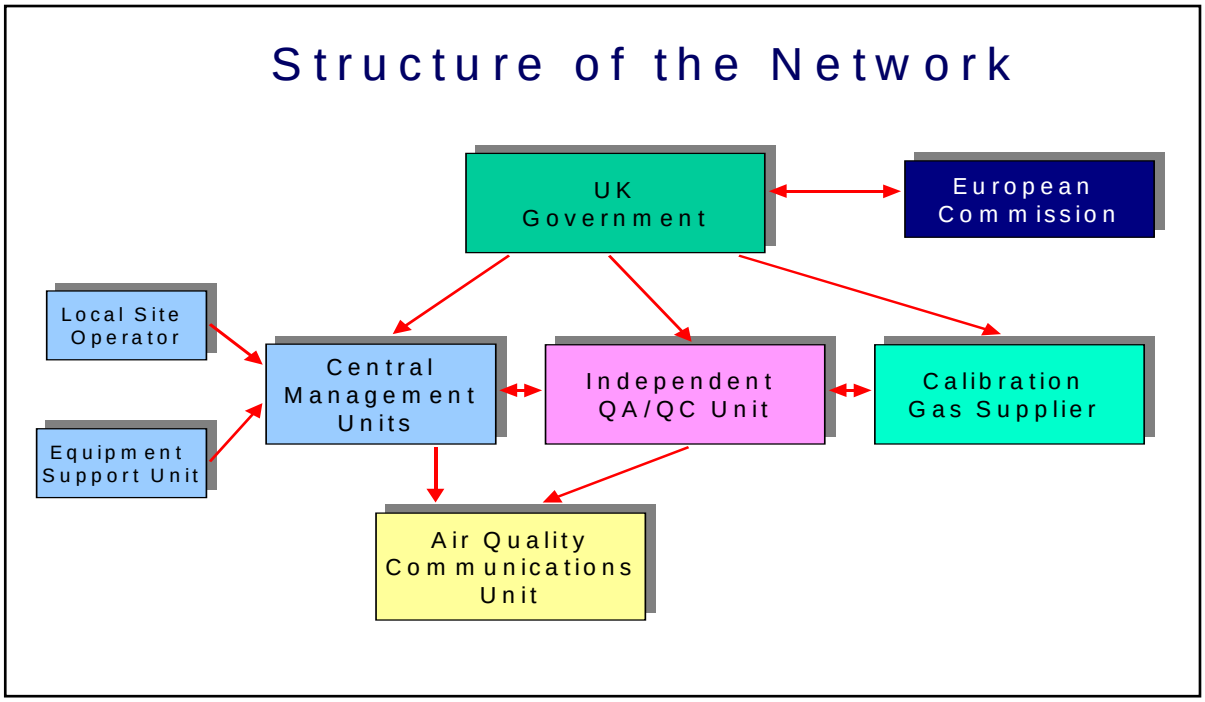


Table 2.1: Network Structure

Role	Contractor
Central Management and Co-ordination Unit (CMCU) for the AURN	Bureau Veritas
Management Unit (MU) for the LAQN	Environmental Research Group
Quality Assurance and Control Unit (QA/QC Unit)	AEA
Calibration Gas Standards Supplier	Air Liquide UK Ltd
Local Site Operator (LSO)	Various organizations*
Equipment Support Unit (ESU)	Various organizations*
Air Quality Communications Unit	AEA

* Full lists of LSOs and ESUs are listed on the AURN HUB website. These lists are updated on a regular basis (see section 2.3.4)

2.5 Air Quality Communications Unit

Though not formally part of the AURN, the Air Quality Communications Unit has a vital role in disseminating the data to the public and media.

AURN monitoring data is uploaded every hour, as provisional data, to the UK Air Quality Information Archive website (www.airquality.co.uk) and to TELETEXT (page 156) and a freephone telephone information service (0800 556677). In addition, they are distributed daily to the media via the air quality bulletin service.

When the data has been further checked and ratified they are re-issued to the Air Quality Information Archive website as ratified data.

The daily data summaries and the hourly data provided to the web, TELETEXT, and the freephone telephone information service are primarily intended to inform the public of current air pollution conditions. Health advice is also provided so that sensitive individuals can take appropriate action, such as increased medication, staying indoors or reducing physical activity. This service also now fulfils the EU requirement for information to be provided to the public and for pollution alerts to be issued when specified alert thresholds are exceeded over a 3 hour period. During severe episodes, the Government may also issue advice to the public on how to reduce pollutant emissions by restricting car use or other polluting activities.

3 Overview of the Automatic Urban and Rural Network

3.1 Objectives of the Automatic Urban and Rural Network

All important decisions in designing networks, selecting sites and instrumentation types, or defining appropriate calibration/operational procedures must ultimately be influenced or determined by the overall monitoring objectives. Before attempting to document site operational and management practice these objectives must be clearly defined.

Previous national scale air quality monitoring networks in the UK, such as the Statutory Urban Network, were established to determine compliance with statutory air quality criteria or to assess temporal/spatial concentrations of pollutants in order to provide a sound basis for government policy development. Originally the Enhanced Urban Network (EUN) was established with the primary objective of collection and rapid dissemination of air quality information to the public. With the amalgamation of the EUN and the SUN, as well as the integration of affiliated sites, the AURN now covers a wider range of monitoring objectives including:

- Checking if statutory air quality standards and targets are met (eg EC Directives);
- Informing the public about air quality;
- Providing information for local air quality review and assessments within the UK Air Quality Strategy;
- Identifying long-term trends of air pollution concentrations; and
- Assessing the effectiveness of policies in controlling pollution

The data may subsequently be used for a variety of other purposes, but these will remain secondary to the prime objectives stated above.

3.2 Organisation of the Network: Division of Responsibility

A brief outline of the principal responsibilities of the network participants is given in Table 3.1 below.

ROLE	ACTIVITIES
CMCUs **Central Management and Coordination Unit and Management Units**	Overall network management Site selection and installation Equipment procurement Appointment and management of local site operators Appointment and management of equipment support contractors Data acquisition from sites Front-end data validation Provide provisional data to Communications Unit and QA/AC unit
QA/QC Unit **Quality Assurance and Control Unit**	Network intercalibrations Site operator audits Preparation and maintenance of operational manuals Local Site Operator training Final data ratification Investigation of poor data Commissioning of new sites Calibration of ESU photometers
Gas Standards Supplier	Provision of gas calibration standards and regulators
LSOs **Local Site Operators**	Management of local site Assist with site installation Routine site calibration and maintenance Emergency call-out visits
ESUs **Equipment Support Units**	Equipment supply and maintenance Emergency response to equipment breakdown Six-monthly equipment servicing Maintain spare equipment and parts inventory
Air Quality **Communications Unit**	Receive hourly data from network managers Compile and disseminate air quality bulletins

Table 3.1: Principal responsibilities of AURN participants

3.3 Advice and Support Services to Local Authorities

This manual describes the operational procedures for the AURN and the monitoring sites within that network. However, it is recognised that these procedures may also be of interest to local authorities undertaking monitoring as part of the process of air quality review and assessment.

To provide specific support to local authority air quality monitoring for review and assessment, DEFRA and the DA's have provided detailed technical guidance which can be found on (http://www.defra.gov.uk/environment/airquality/local/guidance/index.htm) along with an air quality monitoring helpline (0870 190 6050)

3.3.1 Site Information Archive

www.bv-aurnsiteinfo.co.uk

The Site Information Archive is a website prepared by Bureau Veritas that provides information on each monitoring station within the UK Automatic Urban and Rural Network including sites in the London Air Quality Network. Information includes a description of the site, the site address and the pollutants measured together with a location map and photos. The site has recently been updated to provide site locations via a Google Earth platform.

3.3.2 Air Quality Archive

http://www.airquality.co.uk

This web site has been prepared by AEA on behalf of DEFRA and the DAs to provided up to date, comprehensive detailed information on air quality in the UK. The site is also the national archive of air quality information and reports, including detailed air quality monitoring data and statistics, plus major sections on local air quality management and air quality research. Each DA now has a dedicated web site, which contains data for all AURN sites in their territory, together with data from a selection of Local Authority sites.

http://www.scottishairquality.co.uk

http://www.welshairquality.co.uk

http://www.airqualityni.co.uk

3.3.3 Local Air Quality Management Web Site

http://www.airquality.co.uk/archive/laqm/laqm.php

Since 1997 local authorities in the UK have been carrying out a review and assessment of air quality in their area. The aim of the review is to make sure that the national air quality objectives will be achieved. If a local authority finds any places where the objectives are not likely to be achieved, they must declare the area an Air Quality Management Area (AQMA).

The LAQM web site holds information on the progress of each Local Authority in making the review and assessment. It also gives information on any AQMAs declared and the status of any Action Plans.

3.3.4 The AURN Project Information Hub

http://www.aeat.co.uk/com/AURNHUB/index.html

With the rapid growth in the use of the internet as a communication channel, the QA/QC Unit has developed the AURN project information Hub in order to assimilate, store and share project information with all network participants.

The Hub is based on a branch diagram, which links different topic areas within the project. (See Figure 2.1). It provides a wide variety of information in the form of documents and hyperlinks related mainly to the QA/QC Unit's role in the AURN. Information which is of particular relevance to the LSOs includes all network reports and the intercalibration and service schedules.

The Hub has been developed as a password protected Internet site for the network participants. The password can be obtained from Stephen.bird@aeat.co.uk. The website provides ready access to a wide range of AURN related information in a single convenient location.

This web site provides an effective new forum for promoting communication between the Network participants, as well as being a particularly cost-effective way of distributing and up-dating network documentation.

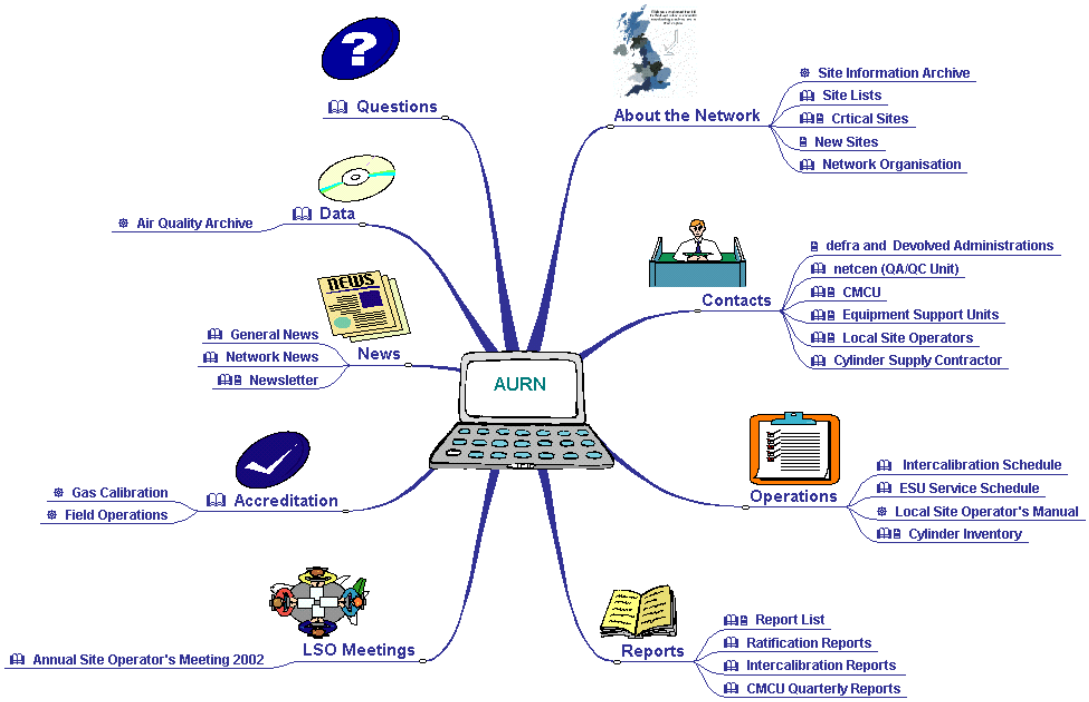


Figure 3.1: The AURN Project Information Hub

3.3.5 Annual LSO Meeting

To promote effective communications with all network participants, the Mangement Units organise an annual meeting for Local Site Operators and other relevant parties, where matters pertaining to the operation of the Network are discussed.

3 Structure and Scope Of The Operational Manual

In any air quality monitoring network, particularly one with devolved and de-centralised functions, it is vital that the responsibilities of all participants are known and documented. This documentation describes specific operational and maintenance procedures which are designed to ensure high data quality and network efficiency.

In order for a full quality system to be applied to the Automatic Urban and Rural Network, it is important that all operations are harmonised and documented. This manual addresses on-site procedures, in order to ensure uniform operation and maintenance of monitoring stations by different site operators and equipment support units.

Specific issues addressed in this site operations manual include:

- Overall requirements for site performance;
- Site selection criteria;
- Station infrastructure;
- Instrumentation;
- Routine and non-routine site operational procedures;
- Routine and non-routine Equipment Support Unit procedures;
- Site housekeeping; and
- On-site calibration procedures.

Although encompassing all important aspects of site operations, this manual in isolation, does not constitute a full quality system for the network: this requires full documentation and standardisation of the performance of the entire measurement chain. It should, therefore, be recognised that some aspects of network operation are not fully addressed here. These include:

- Evaluation and selection of equipment and infrastructure;
- Data handling systems;
- Data scaling, checking and review;
- Long-term data ratification;
- Data dissemination techniques;
- Data bulletins and reports;
- Primary gas calibration procedures;
- Site auditing;

- Network intercalibrations; and
- Traceability chains for the network.

Part A of this manual provides general background information on the objectives, structure and management of the network. Part B covers routine and non-routine site operations to be carried out by the Local Site Operator as well as a description of the procedures to be carried out by the Equipment Support Unit.

Quality assurance and control methodologies are not static. QA/QC is an ongoing process, in which revised or more sophisticated methodologies may be introduced as circumstances change, new needs arise or additional resources become available. Corresponding operational manuals must therefore also be evolving documents. This manual is therefore modular, to allow for any updates of individual sections of the text. Amendments will be issued as and when required on the web version of the manual at the following address:-

(http://www.aurnhub.co.uk/lsoman.html for passwords contact stephen.bird@aeat.co.uk)

Local Site Operators will be responsible for incorporating the new amendments into their copy of the manual

4 Quality Assurance/Control Objectives

Good data quality and high data capture rates are essential if the AURN is to achieve its objectives. To ensure that data is sufficiently accurate, reliable and comparable i.e., consistent data quality assurance/control (QA/QC) procedures are applied throughout the network.

Good QA/QC practice covers all aspects of network operation, including systems design and site selection, equipment evaluation, site operation, maintenance and calibration, data review and ratification. The successful implementation of each component of the QA/QC scheme is essential for the success of the programme.

The fundamental aims of a quality assurance/control programme are as follows:

- The data obtained from measurement systems should be representative of ambient concentrations existing in each urban and rural area;
- Measurements must be accurate, precise and traceable;
- Data must be comparable and reproducible. Results from this geographically extended network must be internally consistent and comparable with international and other accepted standards;
- Results must be consistent over time; and
- In order for seasonally or annually averaged measurements to be meaningful, an appropriate level of data capture is required throughout the year.

The National Measurement System (NMS) exists to provide a formal infrastructure for all measurements in the United Kingdom. At its core there are primary standards held by the National Physical Laboratory, together with appropriate absolute or traceable metrology standards maintained at other designated laboratories. Essential requirements for conformity with the NMS are as follows:

- Measurement methods used must be of known performance and defined scope of application;
- All calibrations must be traceable through an unbroken chain to international standards (the SI system);
- Measurements should be made within a documented quality system; and
- Where possible, measurements should be harmonised with those made by organisations both within and outside UK.

This operational manual describes the documented procedures and record keeping systems necessary to ensure that on-site network operations comply with the overall QA/QC programme objectives specified above, and are also compatible with the requirements of the UK National Measurement System.

Documenting procedures is, in itself, insufficient to ensure good practice. In order to ensure that on-site operations are compatible with the requirements of the QA/QC programme full training is given to the LSOs by the QA/QC Unit.

This training is intended to ensure that the site operators are fully conversant with the monitoring techniques involved and with the network procedures required to maintain a high standard of performance. Further details of the LSO training programme are given in Chapter 14.

Compliance with documented procedures is also closely monitored by the QA/QC Unit during intercalibrations, audits of site operators and on-going data assessments. It is a requirement that LSOs must make themselves available for an intercalibration visit if a member of the QA/QC requests that they do so.

5 Data Requirements

The primary data objective of the AURN is to comply with the European Union's Air Quality Directive (Directive 2008/50/EC). This Directive sets out data quality objectives regarding the maximum uncertainty of measurements and the minimum data capture. These have been presented in Table 5.2

Table 5.1: Measurement uncertainty objectives given in EU Air Quality Directives

Parameter	Uncertainty for Continuous Measurement[1]	Minimum Data Capture
NO_2, NO_X	15%	90%
SO_2	15%	90%
Particulate Matter	25%	90%
CO	15%	90%
O_3	15%	90%

The methodology for calculating uncertainties are given in the relevant CEN documents. MCERTS is the Environment Agency's Monitoring Certification Scheme that tests analysers to see whether they meet the CEN standards. Only those analysers that meet the CEN standards are shown to be equivalent to the reference method. In compliance to the European Directive all new equipment entering the AURN, from 11 June 2010, must be proven to be equivalent to the reference. All existing analysers used in the AURN should be proven equivalent to the reference method by 11 June 2013. More information on the reference methods can be found in Section 7.

5.1 Data Capture

Data capture rates provide a good indicator of overall network performance and the temporal representativeness of the information gathered. They should not be assessed in isolation, however, as there is a trade-off in the operation of any network between data quality and capture. Overly stringent quality requirements usually involve low capture rates while, conversely, capture rates can always be maximised by relaxing or removing data quality/acceptance criteria. An acceptable compromise is to seek data quality commensurate with the overall aims and objectives of the network and maximise data capture within the constraints thus set. Only if acceptable data quality and high capture rates are achieved can the performance of a network then be regarded as fully satisfactory. The current target data capture requirements for the automatic urban and rural network is 90%, in line with the requirements of the EU Directives.

Data loss in any network can result from a number of factors. The most important in practice are as follows:

- Analyser breakdown;
- Site servicing;
- Site relocation/up-grading;

[1] The percentages for uncertainty in the above table are given for individual measurements averaged over the period considered by the limit value (or target value in the case of ozone). For a 95% confidence interval. The uncertainty for the fixed measurements shall be interpreted as being applicable in the region of the appropriate limit value (or target value in the case of ozone).

- Failure or leak of gas sampling system;
- Data acquisition system failure;
- Power cut or other site disruption;
- Telephone line breakdown;
- Operator error;
- Vandalism;
- Air conditioning faults; and
- Data rejection (after failing QA/QC criteria).

It may be noted that, if properly designed and configured, daily automatic analyser calibrations should not result in loss of hourly average data. In well run networks, the major failure mode will be analyser breakdown: these instruments are complex and 100% reliability cannot reasonably be expected. Although some data loss due to analyser failure is unavoidable (short of deploying back-up instruments), most other failure rates can be minimised by implementing the following:

- Efficient data telemetry (enabling on-site problems to be identified rapidly);
- Backup data storage media on-site;
- Rapid service, maintenance and repair;
- Comprehensive and documented site operational protocols;
- Regular application of these protocols;
- Experienced site operators;
- Proven site infrastructure and system backup; and
- The deployment of proven analyser types.

Detailed analysis of network problems leading to loss of data is provided in the quarterly and annual data ratification reports produced by the QA/QC Unit and available on the reports database on the Air Quality Archive (www.airquality.co.uk) and on the AURNHUB (see sections 2.3.2 and 2.3.4).

The main reason for data loss in the network is analyser breakdown. For sites that are owned by DEFRA it is up to the CMCUs to notify the ESUs, for sites that are affiliated to the AURN it is up to the site operators (usually Local Authorities) to notify the ESUs of any breakdowns. It is of utmost importance that the ESU attend call outs as soon as possible to minimise analyser downtime. For DEFRA owned sites the ESUs are required to attend to the fault within 48 hours. For affiliated sites it is hoped that the site operators will have a similar arrangement with their ESUs. An example specification for the servicing and maintenance of air quality monitoring equipment for the Automatic Urban and Rural Networks can be found in the appendix.

6 Network Design and Site Selection

This chapter describes design criteria used for the Automatic Urban and Rural Network and the selection of monitoring site locations.

6.1 Network Design Criteria

The Primary role of the AURN is to fulfil the requirements of the European Union Air Quality Directive 2008/50/EC. For gaseous pollutants The Directive sets out the required minimum number of sampling points, for the protection of human health, per agglomeration/zone. This is based on 2 factors:

- The population of the agglomeration or zone; and
- If maximum concentrations in the agglomeration/ zone exceed the upper assessment threshold (this is not a factor for when calculating the minimum number of sampling points for ozone).

For the protection of vegetation, in zones, the minimum number of sampling points required per unit area depends upon the maximum concentrations detected in the zone.

The Directive introduced the need for monitoring $PM_{2.5}$ as well as the need to continue the monitoring of PM_{10}. $PM_{2.5}$ has been shown to be a non-threshold pollutant therefore the new Directive has introduced an exposure reduction target for $PM_{2.5}$. The target is a percentage reduction in the average exposure indicator by 2020. The average exposure indicator should be a three year running annual mean concentration averaged over all sampling points. Because of the need for an average exposure indicator it has been necessary to introduce new $PM_{2.5}$ analyser into the AURN.

With the introduction of The Directive it was deemed that the AURN had many more SO_2 and CO analysers than it required for this reason many SO_2 and CO analysers were turned off late 2007/ early 2008. On the other hand it was also deemed that the AURN did not have enough NO_x analysers it required and for this reason it has started to incorporate more NO_x analyser either via affiliation of existing sites or the construction of new sites into the network.

6.2 The Distribution of Pollutant Species in Urban Areas

The five principal polluting species, NO_x (NO + NO_2), SO_2, CO, O_3 and PM (sub-divided into PM_{10} and $PM_{2.5}$) have different sources and hence, in some cases, different spatial distributions.

6.2.3 Oxides of Nitrogen

Nitrogen dioxide (NO_2) is one of a number of important oxides of nitrogen present in the atmosphere. Nitric oxide (NO) and nitrogen dioxide (together termed NO_x) are the most abundant man-made oxides of nitrogen in urban areas; these are formed in all high temperature combustion processes, although NO predominates. Nitric oxide is not generally considered to be harmful to health at the concentrations found in the ambient atmosphere.

For the UK as a whole, approximately 45% of all oxide of nitrogen emission originates from motor vehicles, with most of the remainder arising from power stations and other industrial sources.

Since power station and industrial emissions are usually from elevated sources, motor vehicles represent by far the largest source of low level NO_x emission and therefore make the largest contribution (about 75% or more) to long term ground level concentrations in urban areas. Hence, the highest NO_x levels in cities are generally observed at kerbside locations. However, since much of the NO_2 is formed from primary emissions of NO by time dependent oxidation processes in the atmosphere, the relative decline in NO_2 concentration away from the kerbside is slower than for NO.

Modelling and monitoring studies (eg with diffusion tube samplers) have shown that, in general, NO_2 concentrations are greatest in central urban areas. However, this cannot always be assumed to be the case, especially where major road systems, industrial areas or other large sources are located away from city centre areas.

6.2.4 Sulphur Dioxide

Sulphur Dioxide (SO_2) is formed by the oxidation of sulphur impurities in fuels during combustion processes. The largest contribution to SO_2 emissions is from power stations, which accounted for 55% of the total emissions in 2005.

Since 1970 there has been an overall reduction of more than 89% in SO_2 emissions. This is due to a number of factors including; the reduction of coal used as a domestic fuel, the increased use of low sulphur fuels such as natural gas and the increasing numbers of nuclear power stations over the period.

Geographically, SO_2 concentrations in the UK are highest in urban areas where there is still significant use of coal for domestic heating, such as mining regions in the north of England and in N. Ireland. Modelling studies have indicated that the highest SO_2 concentrations in cities usually occur in the central areas.

6.2.5 Carbon Monoxide

Carbon monoxide in urban areas results almost entirely from vehicle emissions. The emission rate for individual vehicles depends critically on vehicle speed, being highest at very low speeds. Since CO is a primary pollutant, its ambient concentrations closely follow emissions. In urban areas, concentrations are therefore highest at the kerbside and decrease rapidly with increasing distance from the road. Since traffic is by far the most important source of CO, its spatial distribution will follow that of traffic: this will generally result in the highest levels being observed in the city centre.

6.2.6 Ozone

A background ozone concentration exists in the atmosphere due to mixing of ozone from the stratosphere and its generation in the troposphere. The background concentration depends on latitude and time of year: in the UK, measurements show the annual average to be about 35 ppb. Lower average ozone concentrations are observed in urban areas, since this background ozone is depleted by deposition to surfaces and reaction with other pollutants (primarily NO_x) in the atmosphere.

Ozone is not emitted directly into the atmosphere in any significant quantity and its presence in the lower atmosphere at concentrations exceeding the background results primarily from a complex series of reactions involving NOx and hydrocarbon precursors in the presence of sunlight.

The reactions producing ozone occur, under appropriate meteorological conditions, in the plume of such sources as it moves downwind; ozone formation can occur over a timescale of a few hours to several days. As a result, ozone concentrations are de-coupled temporally and spatially from precursor sources and ambient concentrations that are strongly dependent on meteorological conditions, together with scavenging and deposition rates.

In urban areas, chemical scavenging by NO_x emissions will result in highly variable ozone concentrations over small spatial scales, with concentrations at lowest where corresponding levels of other pollutants such as NO are highest. In cities, therefore, ozone concentrations will tend to be lower in central areas and increase in the suburbs, although the spatial variation will be complex and, in open spaces in urban areas, levels of ozone may approach those found in nearby rural areas.

6.2.7 Particulate Matter

Airborne particulate matter can be found in ambient air in the form of dust, smoke or other aerosols. Particles may be either directly emitted into the atmosphere (primary particles) or formed there by chemical reactions (secondary particles). Both particle size, usually expressed in terms of its aerodynamic diameter, and chemical composition are greatly influenced by its origin. As well as contributing to poor visibility and soiling effects, particulate matter also has well documented effects on human health.

PM_{10} (the mass fraction of particles collected by a sampler with a 50% inlet cut-off at aerodynamic diameter 10µm) is appropriate for monitoring studies which are mainly concerned with assessing health related effects. Major man-made sources in the urban atmosphere include vehicle emissions (diesel), industrial processes, domestic coal burning, power stations, incinerators and construction activity.

Existing PM_{10} data show that daily average concentrations are highest in the winter months and lowest in the summer. During winter episode periods increases in PM_{10} levels usually occur in association with rises in other traffic related pollutants such as oxides of nitrogen. During the summer the photochemical oxidation of sulphur dioxide and oxides of nitrogen to particulate sulphate and nitrate is another important source.

$PM_{2.5}$ (the mass fraction of particles collected by a sampler with a 50% inlet cut-off at aerodynamic diameter 2.5µm) is of an increasing concern, as it is believed that it penetrates deeper into the lungs than PM_{10} and is harder for the body to remove. For this reason many more $PM_{2.5}$ analysers have been incorporated into the AURN. Another change in the network is the introduction of analysers that can measure both non-volatile and volatile particulate matter.

6.3 Fulfilling the requirements of the EU Directives

For compliance with the EU Air Quality Directives the UK has been split into zones and agglomerations (Figure 6.1). Agglomerations are continuous urban areas with a population of more than 250,000 (there are 28 agglomerations in the UK). The remainder of the country has been split into 15 zones. These coincide with Government statistical regions in England and areas defined by the respective DA's in Wales, Scotland and Northern Ireland.

The European Union's Air Quality Directive 2008/50/EC set minimum requirements for air quality monitoring in each zone and agglomeration and the AURN has been and optimised during 2007/08 to ensure that these monitoring requirements are fulfilled. Note that as a result of these changes, the concept of critical sites is no longer meaningful and has been discontinued.

The following macro-scale siting requirements defined in the Air Quality Directives must also be complied with.

1. Protection of Human Health

(a) Sampling points directed at the protection of human health shall be sited in such a way as to provide data on the following:

- The areas within zones and agglomerations where the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value(s); and

- Levels in other areas within the zones and agglomerations which are representative of the exposure of the general population,

(b) Sampling points shall in general be sited in such a way as to avoid measuring very small micro-environments in their immediate vicinity, which means that a sampling point must be sited in such a way that the air sampled is representative of air quality for a street segment no less than 100 m length at traffic orientated sites and at least 250 m × 250 m at industrial sites, where feasible;

(c) Urban background locations shall be located so that their pollution level is influenced by the integrated contribution from all sources upwind of the station. The pollution level should not be dominated by a single source unless such a situation is typical for a larger urban area. Those sampling points shall, as a general rule, be representative for several square kilometres;

(d) Where the objective is to assess rural background levels, the sampling point shall not be influenced by agglomerations or industrial sites in its vicinity, i.e. sites closer than five kilometres;

(e) Where contributions from industrial sources are to be assessed, at least one sampling point shall be installed downwind of the source in the nearest residential area. Where the background concentration is not known, an additional sampling point shall be situated within the main wind direction;

(f) Sampling points shall, where possible, also be representative of similar locations not in their immediate vicinity;

(g) Account shall be taken of the need to locate sampling points on islands where it is necessary for the protection of human health.

2. Protection of Vegetation and Natural Ecosystems

Sampling points targeted at the protection of vegetation and natural ecosystems shall be sited more than 20 km away from agglomerations or more than 5 km away from other built-up areas, industrial installations or motorways or major roads with traffic counts of more than 50 000 vehicles per day, which means that a sampling point must be sited in such a way that the air sampled is representative of air quality in a surrounding area of at least 1 000 km2. A Member State may provide for a sampling point to be sited at a lesser distance or to be representative of air quality in a less extended area, taking account of geographical conditions or of the opportunities to protect particularly vulnerable areas.

Account shall be taken of the need to assess air quality on islands.

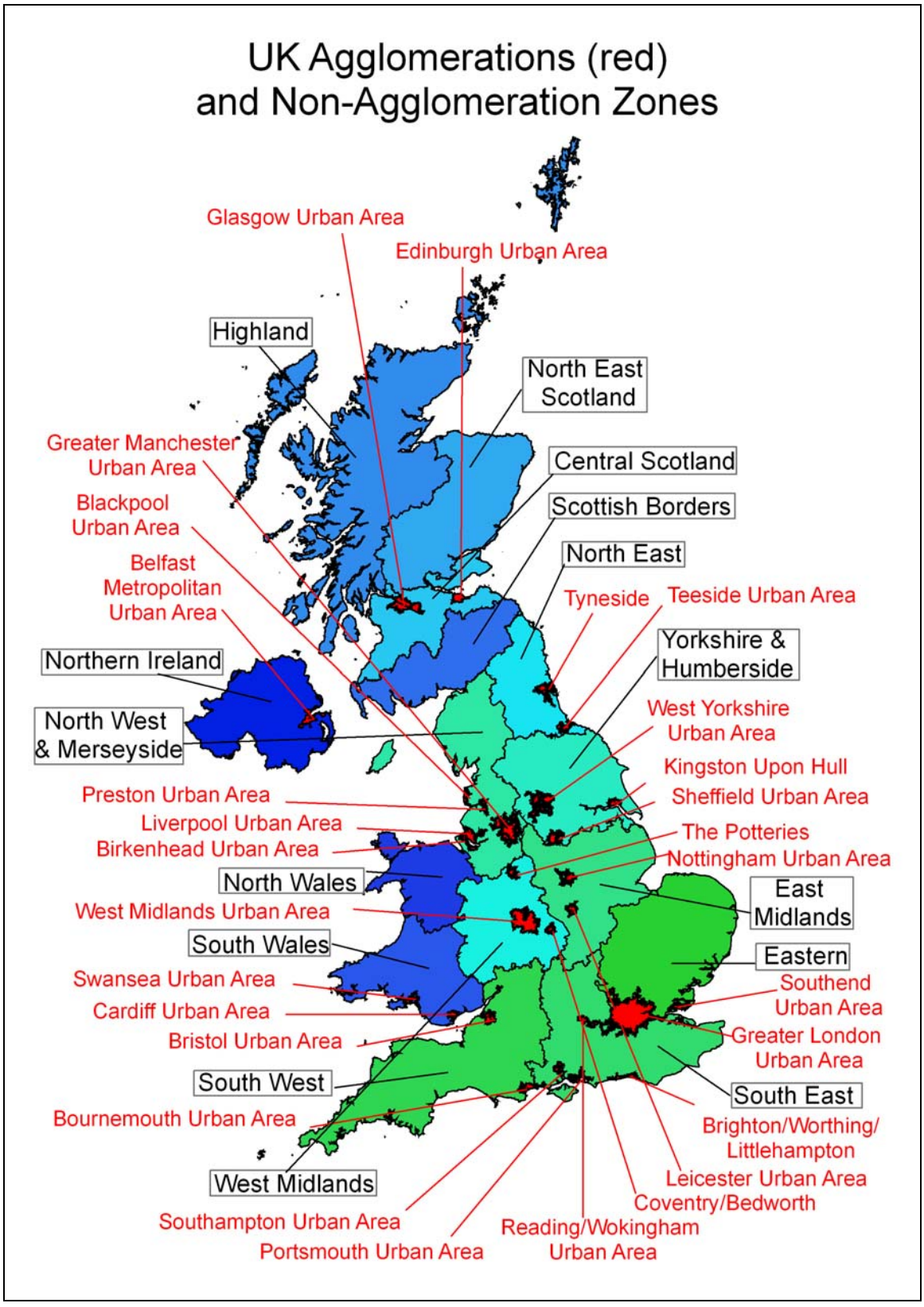


Figure 6.3.1: UK Zones and Agglomeration

Table 6.3.1: Table showing the populations of the zones and agglomerations

Agglomeration	Population
Greater London Urban Area	7,791,139
West Midlands Urban Area	2,083,891
Greater Manchester Urban Area	1,846,479
West Yorkshire Urban Area	1,150,737
Tyneside	721,105
Liverpool Urban Area	697,951
Sheffield Urban Area	521,984
Nottingham Urban Area	558,935
Bristol Urban Area	488,798
Brighton/Worthing/Littlehampton	388,893
Leicester Urban Area	374,314
Portsmouth Urban Area	358,696
Teesside Urban Area	302,559
The Potteries	266,188
Bournemouth Urban Area	340,957
Reading/Wokingham Urban Area	305,786
Coventry/Bedworth	277,475
Kingston upon Hull	260,479
Southampton Urban Area	265,231
Birkenhead Urban Area	266,360
Southend Urban Area	220,761
Blackpool Urban Area	218,162
Preston Urban Area	180,687
Glasgow Urban Area	1,083,323
Edinburgh Urban Area	432,414
Cardiff Urban Area	264,395
Swansea Urban Area	191,717
Belfast Metropolitan Urban Area	517,811

Zone	Population
Eastern	4,965,853
South West	4,105,371
South East	6,231,026
East Midlands	3,263,622
North West & Merseyside	3,503,815
Yorkshire & Humberside	3,022,575
West Midlands	2,624,016
North East	1,489,985
Central Scotland	1,916,281
North East Scotland	1,001,550
Highland	372,539
Scottish Borders	254,141
South Wales	1,717,133
North Wales	716,839
Northern Ireland	1,167,417

6.3 Site Classification

6.3.1 Site Selection - General Location

From the description of the distribution of pollutant species in the urban environment (Section 6.2), it can be concluded that the highest concentrations of NO_2, CO and SO_2 are likely to be found in the central city areas close to busy roads. However, ozone levels will be depressed in such locations.

The original objective of the EUN was to monitor at sites with representative levels of pollution to which the public are generally exposed for significant periods of time. It was not intended to monitor extreme levels, for instance those found along the kerbside, to which people are usually exposed for very short periods.

Within this philosophy urban network sites have generally been located in central city areas, but at locations not unduly influenced by a single large source. Such sites may usefully be termed "urban background" or “urban centre” (Section 6.4.2 provides more specific criteria for these sites). Pedestrianised areas are frequently found in city centres, where large numbers of people often spend significant periods of time. These are likely to meet this overall objective of the network and are clearly candidates for the siting of a monitoring station.

The expanded AURN network also now includes monitoring at other urban site types such as kerbside, industrial and suburban as well as at rural sites. In this way a more comprehensive picture of population exposure can be established.

Sites are classified according to their location. The classification system used in the national networks is given in Table 6.3.2. The majority of urban AURN sites are currently urban centre and urban background.

Table 6.3.2: Site Classification System used in the Automatic and Rural Network

Urban Centre	An urban location representative of typical population exposure in towns or city centres e.g. pedestrian precincts and shopping areas
Urban Background	An urban location distanced from sources and therefore broadly representative of city wide background conditions e.g. urban residential areas
Suburban	A location type situated in a residential area on the outskirts of a town or city
Roadside	A site sampling typically within 1 - 5 metres of the kerb of a busy road (although distance can be upto 15 m from the kerb in some cases).
Kerbside	A site sampling within 1 metre of the kerb of a busy road
Industrial	An area where industrial sources make an important contribution to the total pollution burden.
Rural	An open countryside location, in an area of low population density distanced as far as possible from roads, populated and industrial areas.
Remote	A site in open country, located in an isolated rural area, experiencing regional background pollutant concentrations for much of the time
Other	Any special source-orientated or location category covering monitoring undertaken in relation to specific emission sources such as power stations, car parks, airports or tunnels.

6.3.2 Site Selection - Detailed Urban Location

Once a suitable part of the city in which to monitor has been identified, certain local factors need to be taken into account in selecting the precise location for the monitoring station. The intention is to select a site that is broadly representative of the quality of the air experienced by people in that part of the city during their normal lives. In other words, the sampling site should not represent a "special case".

It is recognised that it is very difficult to identify a "representative" site, particularly when taking into account factors such as visual impact and planning permission. However, in order to ensure meaningful comparisons of data between different stations, sites should be classified according to the scheme given in Table 6.3.1. In addition, in order to meet the overall requirements for urban centre or background sites, the following criteria should be employed as far as possible.
The site should ideally be located where a significant number of people spend their time.

- It should be in as open a setting as possible in relation to surrounding buildings;
- Immediately above and should be open to the sky, with no overhanging trees or buildings; and

- The sample intake should be no higher than 10 m above local ground level and ideally between 1.4 m and 4 m.

For Urban Centre or Background Sites:

There should be no major sources of pollution within 50 m. e.g. a large multi-storey car park. There should be no medium sized sources within 20 m. e.g. petrol stations, ventilation outlets to catering establishments etc.

Cars/vans/lorries should not be expected to stop with their engines idling within 5 m of the sample inlet.

The site should not be within:

- 30 m of a very busy road (>30,000 vehicles/day);
- 20 m of a busy road (10,000-30,000 vehicles/day); and
- 10 m of any other road (<10,000 vehicles/day).

The surrounding area, within say 100 m, should not be expected to undergo major re-development, so as to avoid disruption and to allow long term trends to be followed.

For traffic related sites:

The site should be within 1 m of the kerb (kerbside sites); and.
The site should be within 1-5 m of the kerb (roadside sites).

For industrial sites:

- Where specific sources are being targeted, monitoring should be carried out at the point of maximum impact as determined by modelling.

In addition to the above, there are a number of practical considerations to be taken into account.

- It should be practical for power and telephone connections to be made;
- The site should be accessible for a lorry to deliver the housing;
- It should be reasonably easy for gas cylinders to be delivered close to the site and transferred to the housing without difficulty;
- There should be easy access to the site at all times;
- The site should be in an area where the risk of vandalism are minimal; and
- Account will need to be taken of visual impact and opportunities to "hide" the housing using pre-existing structures.

For compliance with the EU Directives, the following micro-scale siting requirements must also be complied with.

EU Directive Micro-scale siting

The following guidelines should be met as far as practicable:

− The flow around the inlet sampling probe shall be unrestricted (free in an arc of at least 270°) without any obstructions affecting the airflow in the vicinity of the sampler (normally some metres away from buildings, balconies, trees and other obstacles and at least 0.5 m from the nearest building in the case of sampling points representing air quality at the building line),

− In general, the inlet sampling point shall be between 1.5 m (the breathing zone) and 4 m above the ground. Higher positions (up to 8 m) may be necessary in some circumstances. Higher siting may also be appropriate if the station is representative of a large area,

− The inlet probe shall not be positioned in the immediate vicinity of sources in order to avoid the direct intake of emissions unmixed with ambient air,

− The sampler's exhaust outlet shall be positioned so that re-circulation of exhaust air to the sampler inlet is avoided,

− For all pollutants, traffic orientated sampling probes shall be at least 25 m from the edge of major junctions and no more than 10 m from the kerbside.

The following factors may also be taken into account:

− Interfering sources;
− Security;
− Access;
− Availability of electrical power and telephone communications;
− Visibility of the site in relation to its surroundings;
− Safety of the public and operators;
− The desirability of co-locating sampling points for different pollutants; and
− Planning requirements.

7 Monitoring Instrumentation

7.1 Selection of Monitoring Equipment

The selection of appropriate instruments is essential to the success of any monitoring network in achieving its stated objectives. The objectives of the Automatic Urban and Rural Network (AURN) require precise time resolved measurements, necessitating the use of automatic analysers.

The selection of instruments for the AURN was based on specific and proven analytical techniques for the pollutants measured (Table 7.1).

Table 7.1 Operating Principles of Automatic Analysers used in the AURN

Pollutant Measured	Operating Principle
O_3	UV Absorption
NO/NO_2	Chemiluminescence
SO_2	UV Fluorescence
CO	IR Absorption
$PM_{10}/PM_{2.5}$	TEOM (Tapered Element Oscillating Microbalance) FDMS (Flow Dynamic Measurement System) BAM (Beta Attenuation Monitor) Gravimetric Sampler

These techniques represent the current stat of the art for automated monitoring networks and, with the exception of the automatic $PM_{10}/PM_{2.5}$ analysers, are the reference methods of measurement defined in the EU Directives.

7.1.1 CEN

The EU requirements for achieving appropriate data quality are stated by the European Committee for Standardisation (CEN – Comité Européen de Normilisation). These standards specify the detailed performance specifications for reference monitoring methods and include methodologies for sampling, calibration and on-going QA/QC as part of network operation. The instrument performance specification is incorporated into the Environment Agency's MCERTS (Monitoring Certification Scheme) and into other European product certification schemes, such as TUV (Technischer Überwachungsverein – Technical Monitoring Association) in Germany. Typical performance specifications of analysers used in the AURN are given in Table 7.2 and have been taken from the following British Standards documents:

- Ambient air quality – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, BS EN 14211:2005;
- Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence, BS EN 14212:2005;
- Ambient air quality – Standard method for the measurement of the concentration of ozone by ultraviolet photometry, BS EN 14625:2005;

- Ambient air quality – Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infra-red spectroscopy, BS EN 14626:2005;
- Air quality – Determination of the PM_{10} fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods BS EN 12341:1999; and
- Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended matter, BS EN 14907:2005.

Table 7.2: Typical Specifications for AURN Standard Gaseous Pollutant Analysers

Pollutant Measured by Analyser	NO_2	SO_2	O_3	CO
Repeatability: Zero At Limit Value	2 □g m^{-3} 6 □g m^{-3}	2.5 □g m^{-3} 8 □g m^{-3}	2 □g m^{-3} 6 □g m^{-3}	1.2 mg m^{-3} 3.5 mg m^{-3}
Linearity	4%	4%	4%	5%
Period of Unattended Operation	3 months	3 months	3 months	3 months
95% Response Time (max)	180 secs	180 secs	180 secs	180 secs

As already mentioned in previous sections, only analysers that are proven to be equivalent to the reference method are allowed in the AURN by 11 June 2003.

7.1.2 Accreditation

The QA/QC Unit (AEA) holds UKAS (United Kingdom Accreditation Service) accreditation (UKAS Calibration Laboratory No. 0401) to ISO 17025 for the on-site calibration of the gas analysers (NO_x, CO, SO_2, O_3) used in the AURN, for flow rate checks on particulate analysers (PM_{10} and $PM_{2.5}$), and for the determination of the spring constant, k_0, for the TEOM analyser.

The accredited procedures for analyser calibration include the following analyser checks:

- Noise;
- Linearity ;
- Response time ;
- Converter efficiency ;
- SO_2 hydrocarbon interference; and
- Uncertainty evaluation.

The QA/QC Unit also holds UKAS accreditation for laboratory certification of NO, NO_2, CO and SO_2 gas cylinders.

The QA/QC Unit provides ISO17025 accredited calibration services to each ESU ozone photometer prior to the beginning of inter-calibration exercises. The ESU operator is present during the calibration to ensure that the ESU photometer is set up and adjusted correctly and that the operator fully understands the calibration procedure.

All accreditations are examined annually by UKAS. The QA/QC Unit (AEA Group) must demonstrate technical competence and traceability of measurements to recognised metrology standards, in order for the accreditation to be maintained.

7.2 Principle of Operation of Automatic Analysers used in the AURN

7.2.1 UV Absorption Ozone Analyser

Ozone concentrations are calculated from the absorption of ultra-violet (UV) light at 254 nanometres (nm ≡ 10^{-9} m) wavelength. The sample passes through a cell tube of length (l), and the absorption is measured using a UV detector. An ozone removing scrubber is used to provide a zero reference intensity. The analyser alternately measures the absorption I_0 of the air path with no ozone present and the absorption I_1 of the ambient sample. The concentration (c) is calculated using the Beer-Lambert equation:

$$I_1 = I_0 e^{-alc}$$

where ***a*** = absorption co-efficient at 254 nm

These are ultra violet absorption analysers with a single reaction cell and pneumatic valving to switch between zero and ambient air paths (see Fig.D3 Appendix D). Ambient air is sampled using a pump unit. The analysers continually display current O3 concentrations, and depending on the make and model of analyser other parameters can be selected as necessary. An internal ozone generator and zero air scrubber are used to provide daily automatic check calibrations. Chemiluminescent Oxides of Nitrogen Analyser.

Nitric oxide (NO) in the sample air stream reacts with ozone (O_3) in an evacuated chamber to produce activated nitrogen dioxide (NO_2*).

$$NO + O_3 \rightarrow NO_2^* + O_2 \rightarrow NO_2 + O_2 + hv$$

where O_2 = oxygen and hv = the energy of radiation emitted (Joules).

The intensity of the chemiluminescent radiation thereby produced is measured using a photomultiplier tube (PMT) or photodiode detector. The detector output voltage is proportional to the NO concentration. The ambient air sample is divided into two streams; in one, ambient NO_2 is reduced to NO using a molybdenum catalyst before reaction. The molybdenum converter should be at least 95% efficient at converting NO_2 to NO. Separate measurements are made of total oxides of nitrogen NO_x (= NO + NO_2) and NO. The ambient NO_2 concentration is calculated from the difference (NO_2 = NO_x - NO).

These analysers are equipped with either a single or a double reaction chamber and PMT system. The main components of the analyser are shown in Figure D1 Appendix D. A solenoid valve is used to alternatively switch between NO and NO_x (NO + NO_2) measurement typically at 15 second intervals. Ambient air is drawn through the system via a pump and permapure drier unit. The analysers display current NO, NO_2 and NO_x concentrations, and depending on the

make and model of analyser other parameters can be selected as necessary. Either external gas cylinders or an internal permeation oven and zero air scrubber are used to provide daily automatic check calibrations.

7.2.3 UV Fluorescence Sulphur Dioxide Analyser

Ambient air is exposed to UV light, which excites SO_2 molecules in the sample to higher but unstable excited states. These excited states decay, giving rise to the emission of secondary fluorescent radiation.
The fluorescent radiation is detected by a photomultiplier tube, causing an output voltage proportional to SO_2 concentration. A permeable membrane "kicker" is used to remove interfering hydrocarbons before reaction.

These ultra violet fluorescence (UVF) analysers use a filtered UV source and PMT detection system. The main components of the analyser are shown in Figure D2 Appendix D. A UV detector is used to monitor the source radiation and compensate for fluctuations in UV energy. Ambient air is drawn through the system via a pump unit. The analysers continually display current SO_2 concentrations, and depending on the make and model of analyser other parameters can be selected as necessary. Either external gas cylinders or an internal permeation oven and zero air scrubber are used to provide daily automatic check calibrations.

7.2.4 IR Absorption Carbon Monoxide Analyser

Carbon monoxide (CO) concentrations in the sample air are measured by the absorption of infra-red (IR) radiation at 4.5 to 4.9 micrometers ($\mu m \equiv 10^{-6}$ m) wavelength. A reference detection system is used to alternately measure absorption due to CO in the ambient air stream, and absorption by interfering species. An infra-red detector and amplification system produce output voltages proportional to the CO concentration. The concentration is derived from the Beer-Lambert relation described in Section 7.2.1.

These are usually gas filter correlation infra-red absorption analysers. They use a filter wheel to allow alternate measurement of total IR absorption, and that due to interfering species in the absorption band selected (see Fig. D4 in Appendix D). Alternatively, some CO analysers use the similar Non-Dispersive Infra-Red (NDIR) system. Here, differences in IR absorption between ambient air and reference gas (air with all CO removed) cause a metallic membrane in the detector to move back and forth in accordance with the alternating gas flow and CO concentration.

Ambient air is sampled using a pump unit. The analysers continually display current CO concentrations, and depending on the make and model of analyser other parameters can be selected as necessary. An external carbon monoxide in air calibration cylinder and internal air scrubber or laser air cylinder are used to provide daily automatic check calibrations.

7.2.5 Particle Sampling with Fractioning Inlets

The main emphasis in ambient particulate monitoring at present is to determine the concentration of particulate material in the repirable and thoracic size ranges, since these have the greatest significance in relation to human health. The current requirements of the UK Air Quality Strategy and the EU Directive are to measure the PM_{10} size fraction (the thoracic fraction). However, there is also interest in measuring smaller particles – $PM_{2.5}$ (the high risk respirable size fraction). Measurement of these size fractions is achieved by using the appropriate size fractioning inlet head or cyclone cut-off on the particle analyser. New $PM_{2.5}$ analysers will be rolled out across the AURN Network from 2008.

7.2.6 Particulate Analysers/Samplers used in the AURN

TEOM (Tapered Element Oscillating Microbalance)
The tapered element oscillating microbalance (TEOM) system determines particulate concentration by continuously weighing particles deposited on a filter. The filter is attached to a hollow tapered element, which vibrates at its natural frequency of oscillation.

As particles progressively collect on the filter the frequency (***f***) changes by an amount proportional to the mass deposited (***m***):

$$m = k_0/f^2$$

where k_0 is a constant determined during calibration of the TEOM analyser.

The flow rate of air through the system is controlled using thermal mass flow controllers and automatically measured to determine mass concentration. The filter must be manually changed before the mass loading is at the maximum allowed by the system.

The TEOM analyser consists of a sample inlet head attached to the sensor unit, a control unit containing the mass flow controllers and system software and a carbon vane pump. The total flow of 16.67 litres per minute through the sampling head is divided using a flow splitter to give a main flow of 2 (or 3) litres per minute ($l.min^{-1}$) through the filter cartridge and an auxiliary flow of 14.67 (or 13.67) $l.min^{-1}$. The lower sample flow rate of 2 $l.min^{-1}$ is often selected to prolong filter lifetime, although the higher flow rate setting provides superior analyser response/noise characteristics, and is, therefore, to be recommended where possible.

The mass concentration, oscillation frequency, filter loading, flow rates, temperature and other diagnostic information can be displayed on the controller's LCD screen. In addition, mass concentration and filter loading are output to the data logger as analogue voltages or through the RS232 interface. The mass concentration is given at the reference conditions of 20°C and 1 atmosphere. The local site operators are not required to calibrate the TEOM, but must change the filter cartridge as detailed in Appendix A. The auxiliary flow cartridge will be replaced once every six months as part of the service and maintenance procedure.

FDMS (Filter Dynamic Measurement System)
The filter dynamic measurement system (FDMS) has been developed as a retrofit instrument to most existing TEOM analysers and, therefore, the above principle of measuring PM mass concentration can be used. The FDMS unit will be fitted to all existing TEOM's within the AURN from 2008.

When added to the TEOM, the FDMS unit allows measurement of both non-volatile and volatile components of particulate matter (PM) and closely correlates with the gravimetric PM mass concentration, as measured with a reference sampler.

The FDMS analyser consists of a sample inlet head attached to the FDMS unit, which is connected to the sensor unit, a control unit containing the mass flow controllers and system software, and a carbon vane pump. As with the TEOM, the FDMS samples ambient air with a flow rate of 16.67 $l.min^{-1}$ through the sampling head. Again, this flow is divided using a flow splitter to give a main flow of 3 $l.min^{-1}$ through the FDMS and filter cartridge, and an auxiliary flow of 13.67 $l.min^{-1}$. A lower flow rate of 2 $l.min^{-1}$ for the main flow is not required when using the FDMS.

In order to measure both volatile and non-volatile components of PM, the FDMS uses a switching valve to switch between a "base" measurement and "reference" measurement every six minutes.

During the “base” measurement, the FDMS samples as a normal TEOM through the sensor unit filter and weighs the PM. During the “reference” measurement, the FDMS diverts the flow through a purge filter in order to remove all PM from the airstream and the filter is weighed again.

The total PM measured during the 12 minute cycle is:

Mass Concentration = Base Concentration – Reference Concentration

During the “reference” measurement, any volatiles collected on the sensor unit filter with evaporate giving a negative mass concentration. This concentration is subtracted from the “base” measurement concentration to give the total PM present.

The mass concentration, base mass concentration, reference mass concentration, oscillation frequency, filter loading, flow rates, temperature and other diagnostic information can be displayed on the controller's LCD screen. In addition, mass concentrations, filter loading and other diagnostics are output to the data logger as analogue voltages or through the RS232 interface. The mass concentrations are given at ambient temperature and pressure. The local site operators are not required to calibrate the TEOM, but must change the filter cartridge and the purge filter as detailed in Appendix A and the purge filter. The auxiliary flow cartridge will be replaced once every six months as part of the service and maintenance procedure.

BAM (Beta Attenuation Mass Monitor)
The mass density is measured using the technique of beta radiation attenuation. A small beta source is coupled to a sensitive detector, which counts the beta particles. As the mass of particles increases the beta count is reduced. The relationship between the decrease in count and the particulate mass is computed according to a known relationship - Beer-Lambert equation shown in Section 7.2.1.

The beta-ray monitor consists of a paper band filter located between a source of beta rays and a radiation detector. A pump draws ambient air through the filter and the reduction in intensity of beta radiation measured at the detector is proportional to the mass of particulate deposited on the filter.

The calibration of the BAM is performed by measuring the absorption of a blank filter tape and a calibration control membrane with known absorption co-efficient.

The monitor can be set to operate for ¼ to 24 hour cycles with intermediate averages if selected. The sampler will automatically take a measurement and feed the tape on if the filter loading reaches a pre-determined level.

When operated with a PM_{10} sampling head, the monitor is set to operate at a flow rate of 16.7 $l.min^{-1}$.

Gravimetric Sampler
Particulate matter is collected on a 47mm filter, which is subsequently analysed to determine the mass content. Filters are exposed for 24 hours (midnight GMT to midnight GMT) thus providing daily average concentration data.

The Partisol 2025 currently used in the AURN has been designed to meet regulatory monitoring requirements for PM_{10}, $PM_{2.5}$ and other particulate fractions in the US, Europe and other countries. An active volumetric flow control system maintains a constant volume flow rate at a level specified by the user (16.7 $l.min^{-1}$) incorporating a mass flow controller and ambient temperature and pressure sensors. This flow rate provides the requisite $1m^3.hr^{-1}$ volumetric flow for the sample head to maintain its size fraction separation. The sampler uses standard 47 mm filter media enabling post exposure analysis of collected material.

A filter storage and exchange system enables the instrument to collect daily samples for a period of up to 16 days before operator intervention is required. The temperature of the collection filter is maintained to within 5°C of the outdoor ambient temperature.

Filters are conditioned in a temperature and humidity controlled environment for 48 hours before being weighed both pre and post exposure.Care should be exercised when comparing PM_{10} concentrations made using these four techniques (TEOM, FDMS, BAM, Gravimetric). Analysis has shown that measurements made using the TEOM are approximately 1.3 times greater than the gravimetric PM_{10} instruments. One difference is that the TEOM sample filter is maintained 50°C to keep the filter dry, while the other two techniques sample at ambient temperature. The addition of the FDMS unit to the TEOM ensures that no correction factor is required.

7.3 Operator's Guide to Analysers

The on-site analysers (except for the PM_{10} analyser) are usually housed in temperature controlled rack units which also contain the data logger and auto-calibration system, where installed. Block diagrams showing the main components of the analysers are given in Figures D1-D4 Appendix D. There may be slight operational differences between different analyser makes and models.

However, the measurement methodology will be the same. The manufacturer's operational manual for each analyser will also be available on-site. The local site operators are routinely required to calibrate the analysers, change sample inlet filters and perform analyser and site checks, as fully described in Appendix A of this manual.

7.4 Adaptive/Kalman Filters

Many of the gaseous pollutant analysers use adaptive/Kalman filters. This technology is used to detect rapid changes in pollutant concentrations. The analyser changes its averaging time to constant, in order to match the changes in the profile of the ambient sample. This could affect the response characteristics of the analyser if the changes in pollutant concentration are not stable, the effect of which could be a very smooth trace. It is important that the adaptive filtering is set in accordance with the setting used in the tests carried out, and the corresponding time constant is set to 30 seconds, which is a reasonable compromise between quick response and low noise.

8 Data Logging And Data Transmission Equipment

Two methods of data logging are used in the AURN. The analysers themselves either contain data logging capabilities or, standalone loggers (which may be PCs) these are used to scan the outputs of the analysers and record data. Both systems can be interrogated by the Management Unit data collection systems.

The logger scans the analyser output approximately every 10 seconds and stores them as 15 minute averages in the logger memory.

The data logger is programmed to trigger the daily analyser autocalibrations using control signals which drive relays to initiate zero and span measurement cycles. Status inputs to the logger from analysers are used to monitor instrumental performance and detect error conditions.

The logger (or analyser) is connected through an RS232 serial interface to an autodial-auto-answer modem operating at a data transmission rate of up to 9600 baud. The modem is connected, via the public telephone system, to the Managements Unit's central computer which automatically collects the logged data.

In the past chart recorders were used to provide a secondary data backup, however they are now unsupported

8.1 Data Retrieval

The CMCU and use a commercially available data retrieval system to poll data from sites on an hourly basis .

9. Station Infrastructure

9.1 Site Safety

General Site Safety

National safety regulations apply, in particular the Management of Health and Safety at Work Regulations (1999) and the Health and Safety at Work etc. Act (1974). The latter applies to all persons connected with the work done by the network, regardless of their organisation. The Act requires that all employees while at work shall:

- "*Take reasonable care for the health and safety of himself and other persons who may be affected by his acts or omissions at work; and"*
- *"As regards any duty or requirement imposed on his employer or any other person by or under any of the relevant statutory provisions to co-operate with him so far as is necessary to enable that duty or requirement to be performed or complied with."*

Employers shall conduct their work:

"In such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety."

In addition, as far as their own employees are concerned, employers shall:

- Provide and maintain *"plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health."*
- Arrange *"for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances;"*
- Provide "such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of his employees;"
- *"So far as is reasonably practicable as regards any place of work under the employer's control, the maintenance of it in a condition that is safe and without risks to health and the provision and maintenance of means of access to and egress from it that are safe and without risks:"*
- Provide and maintain *"a working environment for his employees that is, so far as is reasonably practicable, safe, without risks to health and adequate as regards facilities and arrangements for their welfare at work."*

For further information on site safety contact the relevant Management Unit (CMCU or LAQN MU) or Local Authority (affiliated sites).

9.2 Electrical Safety

For the Defra and the Devolved Administration (DA) owned sites, electrical safety inspections of all monitoring equipment is undertaken on a regular basis during site servicing. The electrical supply to the hut is tested at least every 5 years. At affiliated sites, the individual site owners are responsible for making suitable arrangements for safe operation of electrical equipment and to comply with the law.

9.3 Storage and Handling of Compressed Gas Calibration Mixtures

The calibration gases should be stored and handled in the correct manner as recommended by the manufacturer. Copies of the gas data sheets for each of the 4 gas mixtures which are commonly used in the AURN are given in Appendix C. Note that not all sites will have all 4 gases. Air Liquide UK Ltd kindly supplied these data sheets, although cylinders of different manufacturers may be in use at some sites.

The cylinders should be stored in the housing or rack supplied, and supported securely at all times. Regulators should be left attached to cylinders between calibration visits, but the cylinder valve must be turned off after the calibration is completed unless the gas cylinder is used for the overnight auto-calibration checks, in which case the cylinder must be left with the valves open. Cylinders should be closed off in the following order by following these steps:

1. First of all close the regulator outlet valve (do not over-tighten);
2. Close the main cylinder valve (tightly); and
3. Finally, release the primary regulator valve.

This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Failure to properly shut off cylinders may result in the cylinder contents leaking away; a cylinder will become empty in this way in a matter of hours.

At most sites, replacement calibration cylinders are delivered by the gas manufacturer. The cylinders will be delivered by arrangement, during a scheduled calibration visit. The LSO will be responsible for removing the empty cylinder, and placing the replacement cylinder in the storage rack. The LSO will be responsible for removing the regulator from the empty cylinder, replacing the valve cap and cylinder cap, and re-fitting the regulator to the new cylinder. Training in this procedure will be provided by QA/QC unit staff on an individual basis. Safety glasses should be used during this operation. Leak detection fluid is used for testing the regulator connection following fitting. Should bubbles be detected at the cylinder valve outlet, the nut should be tightened until the leak is stopped. Care should be taken to avoid over tightening fittings. When the regulator is removed, the sealing washer should be inspected and replaced if damaged. Replacements are available from the gas standards supplier (currently Air Liquide UK Ltd).

When changing cylinders, operators should be aware of the different valve outlets currently in use in the network. All CO cylinders have BS15 outlets (left-hand thread), but the NO, NO_2 and SO_2 cylinders may have BS14. Left hand threaded regulators can be identified by notches cut into the corners of the nut.

A 4 to 7 digit number (may contain numbers and letters), which is stamped into the cylinder just below the neck, uniquely identifies the cylinders supplied by Air Liquide UK Ltd; this number is also written on the white dispatch label, which is attached to the cylinder. Any reference to the cylinder in correspondence with the QA/QC unit should include this number.

9.4 Equipment Housing

Some monitoring stations are installed in stand alone, self-contained cabinets with an in-built air-conditioning unit, whilst others are sited in pre-existing buildings. Sites installed in pre-existing buildings

Where the monitoring equipment is installed inside a pre-existing building, the LSO will need to make arrangements with relevant persons or organisations in order to ensure access to the site is available whenever necessary.

9.5 Self-contained Monitoring Sites

Where a number of air quality monitoring analysers are to be housed in stand alone, self-contained cabinets, the housing should be of adequate size (typically 3.0 m x 2.0 m x 2.5 m high) to accommodate the instrumentation specified in Section 7.3. Each housing is typically supplied with:

- Internal electrical wiring and fittings;
- Air conditioning;
- Shelving/racking;
- Sample intake manifold;
- Gas cylinder store; and
- 2 telephone lines for connection to modem and telephone handset (some sites).

The cabinet is typically constructed of steel of 1.5 mm thickness to afford security, with the outer surface coated with glass fibre reinforced plastic (GRP).

With the affiliation of a greater number of Local Authority sites, smaller stand-alone monitoring cabinets will be integrated into the AURN. These compact monitoring cabinets (CMC's) are used at roadside locations where available space is an issue and usually only contain one or two analysers, typically a NO_x analyser and FDMS. Each housing is typically supplied with the following:

- Internal electrical wiring and fittings;
- Air conditioning;
- Gas cylinder rack; and
- GSM modem.

The following information refers primarily to the directly funded Defra and the DAs sites housed in self-standing cabins. Some local authority-owned affiliated sites and those housed in existing buildings may differ slightly in some aspects of the infrastructure.

Electrical Systems

A 240V, 50Hz, 60 amp electrical supply is provided to the housing. All internal electrical wiring and fittings conform to the Regulations for Electrical Installations (IEE Wiring Regulations) 16th Edition, 1991. Separate electrical circuits are provided for:

- Socket outlets;
- Air conditioning unit;
- Lighting; and
- Spare.

Sufficient standard UK 13 amp power sockets are available for the equipment plus spares. These are located so as to minimise accidental disturbance by site operators. The housings have internal fluorescent lighting and an emergency lighting system.

9.6 Air Conditioning

Freestanding monitoring station housings should be fully air conditioned in order to maintain a stable operating temperature of approximately 20-25°C within the enclosure.

Typically, analysers can operate within a temperature range 15-35°C; however, in order to ensure a stable instrument response it is important to reduce the operating temperature variation to a minimum. It is also important that instrument calibrations are performed within a known, consistent and stable temperature range. A constant temperature must be maintained within the enclosure, doors must, whenever possible, be kept closed. The temperature control on the air conditioning unit should only need adjusting at the beginning of the summer and winter seasons.

The air conditioning unit must be able to maintain the internal temperature at 20-30°C with a 3 KW equipment load and an ambient temperature of up to 35°C.

9.7 Cylinder Storage

It is necessary to keep compressed gas cylinders at the site for the purpose of instrument calibration. Depending on the number of analysers on site, the cylinders will be some or all of the following:

- 0.45ppm nitric oxide (NO) in nitrogen for urban monitoring stations 0.2ppm nitric oxide (NO) in nitrogen for rural monitoring stations;
- 0.45ppm nitrogen dioxide (NO_2) in air for urban monitoring stations 0.2ppm nitrogen dioxide (NO_2) in air for rural monitoring stations;
- 0.15ppm sulphur dioxide (SO_2) in air for urban and rural monitoring stations; and
- 20ppm carbon monoxide (CO) in air for urban monitoring stations 1.5ppm carbon monoxide (CO) in air for rural monitoring stations

If a CO analyser is present, there will be a 40ppm (approx) CO cylinder for the daily auto-calibration system. This cylinder is supplied by the management unit in the case of direct funded stations and the local authority in the case of affiliated sites; the calibration cylinders (and their regulators) listed above are supplied by the gas standards supplier.

The gas standards supplier will supply the largest practicable cylinder size for each site; in most cases, this will be L40 size (i.e. 40 litre volume). Due to lack of space, however, some sites will be supplied with L10 size cylinders. All cylinders should be supported securely during storage and use, and the cylinder storage area should be correctly labelled with the appropriate warning labels. The provision of safe cylinder storage facilities is the responsibility of the Management Unit.

9.8 Data sheets for the supplied gases are given in Appendix C

Replacement of on-site gas cylinders

It is the responsibility of the gas standards supplier to ensure delivery of calibrated gas cylinders for the fortnightly instrument calibration. The delivery of these will be undertaken by the gas standards supplier or occasionally by an agent of the supplier.

The delivery will be carried out at a time convenient to the LSO; it is intended that the delivery will be scheduled during a routine calibration visit.

It will be necessary for the LSO to remove the gas regulator from the empty cylinder and replace it on the new cylinder when installed. Although this is a simple procedure, training will be provided by the QA/QC unit where required. Safety glasses should be worn when changing cylinders and regulators. The procedure is as follows:

- Ensure cylinder valve is fully turned off;
- De-pressurise the regulator, by operating the purge valve on the system. The regulator will not unscrew safely when still under pressure;
- Unscrew the regulator using the spanner supplied. Note that BS4 and BS15 (all CO cylinders) are left hand threads i.e. are unscrewed anti-clockwise. Left handed fittings are distinguished by notches cut in the fitting nut;
- Connect the regulator to the new cylinder, ensuring that the sealing washer is intact. When tightening the regulator, apply moderate force only; do not over-tighten;
- Close the regulator outlet valve (small knob) and gently open the cylinder valve; the inlet pressure gauge should rise. Turn the cylinder valve off, and check the regulator fitting for leaks, using “Snoop” leak detector if necessary;
- Purge the air from the regulator by allowing gas from the cylinder to flush out all air in the regulator and line through the purge valve - repeat twice. Air in the system may give false readings and cause the NO calibration gas to become unstable; and
- If the system is on non-continuous operation, pressurise the regulator and close the cylinder valve. The regulator should be left in this pressurised state to ensure there is no ingress of ambient air. If the system is on continuous operation, leave the cylinder valve open, with the system under pressure.

Any problems encountered during this procedure should be reported to the gas standards supplier and CMCU.

The daily CO auto-calibration cylinder and its regulator are the responsibility of the Management Unit in the case of direct funded stations and the local authority in the case of affiliated sites, to whom any problems regarding these should be addressed.

An inventory of the cylinders used in the network is maintained by QA/QC Unit and is available on the AURNHUB website (see section 2.3.4 for address).

9.9 Sampling System

The following applies only to sites fitted with a sampling manifold.

To enable any analyser to correctly monitor pollutant concentrations in the ambient atmosphere, it is essential that all elements of the atmosphere be transferred unchanged to the analysis cell of the instrument. For this reason, a manifold sampling system is used at most sites in the AURN. The manifold is constructed from an inert material such as glass or teflon. The sample probe extends vertically through the roof of the housing to a height of at least 0.5 m, thereby giving 360° unrestricted airflow. The location of the sample inlet is such that ambient sampling is not influenced by gas discharges from the instruments, calibration systems or adjoining installations such as the air conditioning unit. A simple rain hood is installed to prevent water from entering the manifold.

The sampling manifold system has the following design specifications:

- Constructed from inert material;
- Inlet protection against rain, insects or large particulate matter;
- De-mountable for cleaning;

- Sample residence time of less than 5 seconds between the inlet to the manifold and the inlet to the analysers;
- Minimum total flow through the manifold of 20 litres/minute;
- Pressure drop in the manifold system not exceeding 0.25" water; and
- Fitted with outlets for ¼" PTFE tubing for connection to analysers.

An independent suction motor is connected to the manifold to draw in a large excess volume of ambient air from which each analyser samples; the excess air is vented out of the hut. Typical specifications of the air-sampling manifold are given in Table 9.1.

Table 9.1: Typical specifications for air sampling manifold

Manifold material	Glass with Teflon fittings
Length	2500 mm
Internal Diameter	25mm
Flow rate	3.2* metres/second
Residence time	0.8* seconds
Pressure drop	0.25* ins H_2O
Blower speed	3030 rpm

* measured by QA/QC unit.

Although condensation in the manifold is unlikely to be a problem in the ambient conditions prevailing in the UK, a water trap has been included. The manifold is not heated, as this is usually only required in very high temperature/humidity operating conditions.

Ambient gas analysers are individually connected to the sample manifold via 1/4" PTFE (or equivalent) tube. The length of this tube is kept as short as possible and is usually between 1-2 metres. A PTFE filter is held in a PTFE-coated filter holder situated on the front panel of the instrument rack, in order to protect each instrument from ingress of particulate matter. (Another filter is situated at the back of each instrument, but this will only be changed at 6 monthly intervals by the instrument service technicians or QA/QC Unit. If, however, this is the only filter, it will need to be changed by the LSO during routine maintenance/calibration).

9.10 Sample Inlet for Particulate Analyser

A separate sample port (approx 4 cm in diameter) in the roof of the housing is used to feed a sampling tube from the internal TEOM/FDMS/BAM sensor unit to the PM_{10} inlet mounted externally on the roof.
Because of the TEOM/FDMS detection method, it is important for the sensor unit to be mounted on a sturdy platform which is independent from other activities, free from external vibration and, where practicable, isolated from mechanical noise.

Gravimetric samplers (Partisol 2025) are self-contained units located externally of the monitoring enclosure.

9.11 Telephone Lines

In general there are two telephone lines to the monitoring station. One is for data telemetry and is connected directly into the site modem, whilst the other has a normal handset. At some sites, an additional phone line may be installed for the Gravimetric PM_{10} (Partisol) sampler.

Modems

The site modem is used for data communication between the remote central station and the site logger via the site telephone line. The modem requires:

- Mains power;
- A connection to the site telephone wall socket;
- A connection to the logger serial port; and
- Correct programming.

The modem program is held in a battery-backed store and should not require re-entry except after a prolonged power cut.

9.12 Auto-Calibration Facilities

The provision of a daily automatic calibration check on site analysers is an essential part of the overall monitoring quality assurance programme. These performance checks enable rapid remote detection of system faults via the telemetry system, and thereby minimise data loss through instrument malfunction.

The automatic calibration facility provides a zero and span check initiated by the data logger. The data recorded during the calibration are flagged and readily scrutinised by the Management Unit for evidence of faults. The daily calibration cycle is timed to minimise loss of ambient data. Details of the methods and auto-calibration standards used are given in Chapter 10.

10 Calibration Systems: Principles

10.1 Introduction

The production of meaningful data from the Automatic Urban and Rural Network necessitates the regular calibration of all analyser types using traceable transfer gas calibration standards.

To ensure optimum data quality and capture, a three tier system of calibration and analyser test procedures is employed in the AURN. The major components of this system are briefly described below:

- **Daily automatic IZS checks**. These allow instrumental drifts to be examined, and act as a daily check on instrument performance. Results should not be used for data scaling, unless calibration gas is used for IZS (see section 10.2).

- **Fortnightly/monthly manual calibrations**. These are performed by the local site operators, and are used by Management Unit to scale raw pollution data (in mV) into meaningful concentration units. Instrument drifts are fully quantified by calibrating analysers manually with documented and traceable calibration standards. These calibrations will be carried out on a monthly basis, except at roadside sites which are on a fortnightly basis.

- **6-monthly network intercalibrations**. These exercises, performed by QA/QC Unit, ensure that measurements from all network stations are completely representative and intercomparable. In some cases, such as for ozone analysers, the data are directly scaled according to the results obtained from the network intercalibration. The intercalibrations will also act as an independent audit of the system performance at each monitoring site. In this way, any site-specific problems which may have developed and remained undetected are fully quantified. At sites in the AURN, network intercalibrations are undertaken every 6-months.

This chapter of the site operational manual will describe automatic calibration systems and techniques, as well as gas standards to be used by local site operators in their fortnightly site calibrations. Check listed operational procedures for fortnightly instrument calibrations, these are provided in Appendix A. The intercalibration exercises performed by the QA/QC unit are introduced in Chapter 13, but will not be described in detail in this manual.

10.2 Daily Automatic IZS Check Systems and Standards

Daily automatic analyser checks provide valuable information on the routine performance of analysers and any long term response drifts. The checks, consisting of two point zero and span checks, are controlled automatically by the data logger or analyser software, and will not normally need any adjustment. These checks usually take place around midnight.

The principles of operation of automatic zero and span (IZS) devices are given below

10.2.1 NO_X Analyser

Zero air is generated by passing ambient air through purafil and charcoal scrubbers, before being passed into the reaction cell. With time, the quality of the zero air would eventually degrade, as the scrubbers become exhausted.
These are, therefore, replaced at every six month service. Some sites use a zero air cylinder, which can give more consistent zero readings.

Span gas is generated by an NO_2 permeation tube. Zero air at a constant flow rate is passed across the tube which contains a quantity of pure liquid NO_2. The tube is enclosed in an oven maintained at a constant temperature. Provided the flow rate and temperature are kept constant, the amount of NO_2 which permeates from the tube into the air stream will be constant. This gas thus produced then passes into the reaction cell to provide a span calibration response.

Alternatively, on some newer analyser systems the NO calibration gas standard is also used for the autocalibration check. Some systems operate daily, whilst others may operate every two or three days.

10.2.2 SO_2 Analyser

Zero air is generated by passing ambient air through a charcoal scrubber, before entering the reaction cell. Some sites use a zero air cylinder, which can give more consistent zero readings.

Span gas is produced in a similar way to the NO_X analyser, except an SO_2 permeation tube is used in the oven.

Alternatively, on some newer analyser systems the SO_2 calibration gas standard is also used for the auto-calibration check.

10.2.3 Ozone Analyser

Zero air is produced by an internal zero scrubber inside the analyser, before entering the reaction cell.

Span gas is produced by the action of UV light in an ozone generator on the same zero airstream to produce ozone.

10.2.4 CO Analyser

Zero air is generated by passing ambient air through a heated Palladium/Alumina catalyst, before entering the reaction cell. Some sites use a zero air cylinder, which can give more consistent zero readings.

Span gas is supplied from a dedicated CO cylinder attached to the IZS span inlet on the equipment rack.

10.2.5 Particulate Analyser

It is not possible to provide a system to carry out daily automatic calibrations on the particulate analyser.

10.2.6 Transfer Standard Calibration Systems

As fortnightly manual zero and span calibrations are to be used to scale data into meaningful engineering units, it is most important that the calibration gases used are both stable and traceable to primary standards.
The gas standards supplier is responsible for supply and calibration of on-site transfer standards. These standards are maintained and utilised by local site operators in accordance with the directions specified in this manual.

During every calibration visit, a two-point calibration will be performed. This involves determining the response of the analyser when the pollutant of interest has had the following:

- Removal from the sample airstream, (zero response); and
- Present at an accurately known concentration, (span response).

Data scaling factors are determined from these responses, and are used to convert raw voltage data into concentration units, as described in Section 10.4.

The QA/QC unit verifies the integrity of on-site standards every 6 months, during the intercalibration exercise. These network intercalibrations employ an independent standard to determine zero and span response. In order to quantify any drifts in on-site calibration standards which may have occurred during the preceding 6-month period. If standards are found to have undergone significant drifts, these will be replaced.

10.2.7 Production of Zero Air

Two methods of zero air production are used in the AURN, either directly from a cylinder of zero grade air, or by catalytically removing pollutant species from a sample airstream. For the second method, the QA/QC unit has developed a zero air generator which consists of the following components:

- Compressor to produce air sample;
- Water drain to remove liquid water;
- Needle valve to regulate airflow;
- Silica gel to remove water vapour;
- Hopcalite to remove CO;
- Purafil to remove NO;
- Activated charcoal to remove O_3, NO_2 and SO_2; and
- A particulate filter on the system outlet to ensure that no particulate matter, especially scrubber material, is "blown" into the analysers.

A diagram of the zero air generator is given in Figure D5 Appendix D.
Using an "active" system, where air is forced through the scrubbers, as opposed to a "passive" system which has the following advantages:

- The system is far less susceptible to leaks due to the positive pressure caused by the compressor along the flow path;
- The differences between output pressure and atmospheric pressure, i.e over-pressurisation in active and under-pressurisation in passive systems, can be better regulated and controlled in an active system.

At some of the network sites, however, a “passive” scrubber system may be used, in which air is drawn through the scrubbers by the analyser.

The consumable components in the zero air generator is changed routinely at six monthly intervals as part of the service. This will only be done after comparison with transfer zero standard at the QA/QC audit. The zero transfer standard used by the QA/QC Unit for these comparisons will previously have been compared to certified zero air cylinders.

It may however be necessary for the LSO to regenerate or replace the silica gel component at more frequent intervals (see section A3.11 Appendix A).

10.2.8 Silica Gel

QA/QC Unit has replaced all the previously used blue indicating silica gel (cobalt chloride) in the zero air canisters with an orange indicator as the blue material is considered to be harmful and must be treated as hazardous waste for disposal purposes. As there is no difference in the performance of the two materials QA/QC Unit strongly recommends for health, safety and environmental reasons that everyone uses orange silica gel in the zero air scrubbers. Any blue silica gel found in the zero air canisters will be left on site for the LSOs/ESUs to dispose of. A safety data sheet for orange indicating silica gel can be found in Appendix C.

10.2.9 Production of Span Calibration Gases

The gas standards supplier supplies gas cylinders containing calibration gas mixtures of NO, NO_2, SO_2, and CO for calibration of the relevant analysers. These cylinders are purchased from a supplier which has demonstrated compliance with all relevant quality control procedures in the preparation of gas mixtures.

The cylinders are calibrated, prior to being installed on-site, at the gas standards supplier's gas calibration laboratory.

To ensure traceability of measurements in the AURN, all calibration gas standards are required to be calibrated by an organisation accredited to the requirements of ISO17025 by the United Kingdom Accreditation Service (UKAS).

Each cylinder is supplied with its own regulator. This will minimise the possibility of the cylinder becoming contaminated by the use of regulators which contain ambient air or other calibration gases. These regulators must not therefore, be removed from the cylinder under normal operating circumstances. Instructions on how to open and close cylinder/regulator supplies must be strictly adhered to if contamination of the cylinder contents is to be avoided (see Appendix A).

The use of cylinders has health and safety implications. Provision must be made to securely strap cylinders to prevent them from falling; this is especially important as regulators are to be left connected.

To obtain the analyser calibration span points the following calibration gases will be used:

Nitrogen oxides: Nitric oxide (NO) in nitrogen.
Sulphur dioxide: Sulphur dioxide (SO_2) in air; and

Carbon monoxide: Carbon monoxide (CO) in air.

A second span check is undertaken on the nitrogen oxides analyser using a nitrogen dioxide (NO_2) in air mixture.

For all analysers, the span checks are undertaken on the analyser running range. This ensures that errors do not manifest themselves in the data scaling factors as a result of inconsistencies in analyser range ratios.

As there is, at present, no reliable and proven system for performing simple on-site two point calibrations on O_3 and particulate analysers, all calibrations which produce data scaling factors for these instruments will be carried out by the QA/QC Unit.

10.2.10 Utilisation of Calibration Data in Producing Scaled Pollution Data

The two point calibration will quantify the analyser "zero" and "span" response. As the analyser gives an output signal which is recorded and averaged by the data logger, it is vital that zero and span factors are also taken as readings from the data logger (where used) and not solely by reading the instrument display.

The zero response, V_z, is the response in volts of the analyser when the pollutant species being measured is not present in the sample airstream. The span response V_s is the response, again in volts, of the anlayser to an accurately known concentration,c, in ppb, (parts per billion (10^{-9})) or ppm, (parts per million (10^{-6})) for CO, of the pollutant species. Both the zero and span responses will be taken on the concentration range at which the instrument normally operates. Instrument zero response and calibration factors are then calculated using this data as follows:

Instrument zero response = V_Z
Instrument span response = V_S
Instrument calibration factor, $F = c/(V_S-V_Z)$

Ambient pollution data are then calculated by applying these factors to logged voltage output signals as follows:

Pollutant concentration = $F(V_a-V_Z)$

where V_a is the recorded voltage signal from the analyser sampling ambient air. Application of calibration data in this way assumes that the instrument response is linear over the whole concentration/voltage range in use. The linearity of the instrument is checked at six-monthly intervals by the QA/QC Unit.

The data scaling procedures detailed above are used for pollutants for which reliable transfer standards exist. In the case of ozone, however, the UV measurement technique is inherently more stable than the production of ozone concentrations in the ambient range. The fortnightly calibration of ozone analysers does not, therefore, serve to produce data scaling factors.

Ambient $NO/NO_x/NO_2$ data is scaled from the calibration of the NO and NO_x channels of the NO_x analyser, using the NO in nitrogen transfer standard. This will directly output NO and NO_x concentrations, with the NO_2 concentration being given by:

$NO_2(ppb) = NO_x(ppb) - NO(ppb)$

An NO_2 in air calibration mixture will, however, be used as a cross-check on the NO_x channel calibration and to ensure that the catalytic converter in the instrument efficiently reduces NO_2 to NO.

Conversion of concentrations to units of µg m^{-3} or mg m^{-3} at the stated temperature and pressure of 20˚C and 101.3 kPa may subsequently be undertaken. Details of the relevant conversion factors are given in Appendix I.Exact procedures for instrument calibration are detailed in Appendix A.

10.2.11 Use of Calibration Data over Extended Time Periods

Many air pollution analysers undergo some form of drift in sensitivity over time. This may be due to ageing of components such as photo-multiplier tubes, degradation of catalytic scrubbers, (eg ozone scrubbers), or drifts in electronic components.

The possibility exists to routinely adjust instrument sensitivities to align the instrument with the on-site transfer standard. For the following reasons, however, such routine adjustments will **not** be undertaken in the AURN:

- As all instruments in the network are to be checked on a fortnightly basis, any drifts will be easily quantified by consideration of the calibration history of the instruments. It is most important, therefore that this calibration history is not destroyed.
- The transfer standards themselves may drift from their original value. If this were the case and both the analyser and on-site standard were drifting, it would be impossible - having altered the analyser response - to produce a final validated data set. Drifts in the on-site standard will be quantified by QA/QC Unit intercalibration techniques at 6 monthly intervals.
- Routine instrument adjustments may lead to unreliable data being produced as the instrument stabilises. Stabilisation periods may take many hours from the time of the adjustment and, with sites being calibrated/adjusted fortnightly, this could lead to an appreciable proportion of data being degraded in quality.

Calibration results therefore, serve only to scale ambient data. They will not be used to routinely adjust analyser response factors.

As the instruments will not be adjusted, the instrument zero response and calibration factors - V_Z and F - will have to be updated in the Management Units and QA/QC Unit data processing system on a regular basis, following each calibration. For this reason, calibration records must be e-mailed to Management Units and QA/QC Unit immediately after each on-site manual calibration or faxed where paper records are still used.

10.2.12 Calibration During High Pollution Episodes

In order to prevent losing valuable pollution data, it is important to avoid calibrating the analysers during high pollution episodes. The following pre-calibration checks must be performed to confirm if any episode is occurring.

- Examine the analyser front panel reading to see if the instantaneous concentrations are above, or close to, the trigger levels given for each pollutant in Table 10.1. The analyser front panel readings may not be accurate but give an indication appropriate for this purpose.

- If the above criteria are met, the CMCU must be informed before proceeding with the calibration.

Table 10.1: Episode Criteria

Pollutant	Trigger Level (exceeded for ~ 1 hour)
O_3	> ~70 ppb
NO_2	> ~ 75 ppb
SO_2	> ~ 90 ppb
CO	> ~ 10 ppm
PM_{10}	> ~ 100 $\mu g/m^3$